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see page 55

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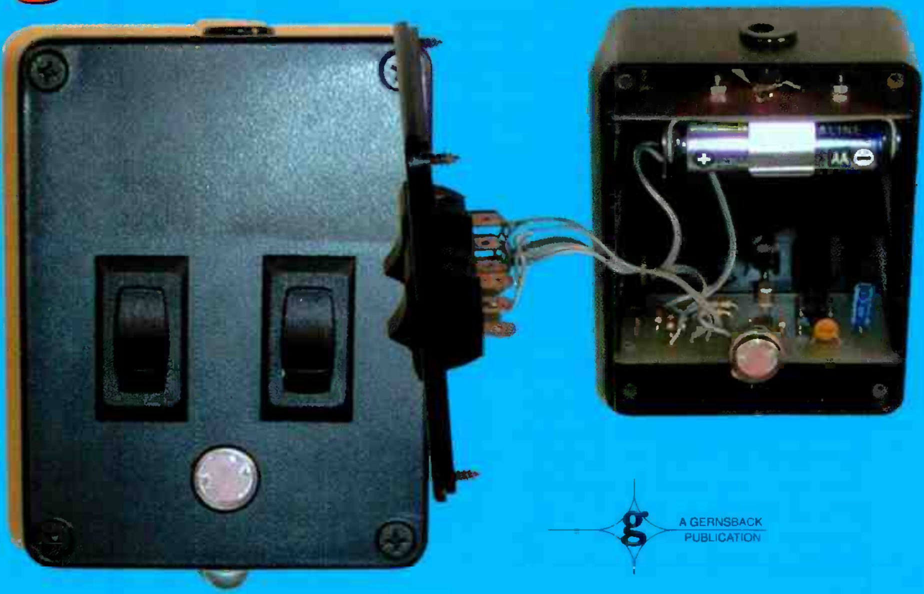

John Hays Hammond, Jr.

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Electronics Now
March 2002, Vol. 3, No. 3
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PRODUCT REVIEWS

DEPARTMENTS

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Poptronics (ISSN 1526-3681) Published monthly by Gernsback Publications, Inc. 275-G Marcus Blvd., Hauppauge, NY 11788. Second-Class postage paid at Hauppauge, NY and at additional mailing offices. One-year, twelve issues, subscription rate U.S. and possessions $24.99, Canada $33.15 (includes G.S.T. Canadian Goods and Services Tax Registration No. R125166280), all other countries $33.99. Subscription orders payable in U.S. funds only, International Postal Money Order or check drawn on a U.S. bank. U.S. single copy price $4.99.

Postmaster: Please send address changes to Poptronics, Subscription Dept., P.O. Box 459, Mount Morris, IL 61054-7629

BUSINESS AND EDITORIAL OFFICES
Gernsback Publications, Inc.
275-G Marcus Blvd.
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...Stranger Than Fiction

Just look at where we are today. How did we get here? The answer is simple...hard work and imagination. Oh, and a massive dose of venture capital for research and development. It seems that money can inspire scientists to achieve monumental leaps in technology or, at least, pay for the fancy equipment. Some of the greatest accomplishments occur when governments join together with private industry to create better ways for living. Proof can be found in the *M*ultiwavelength *O*ptical *Net*work (*MONET*) Consortium, whose members include AT&T, Bell Atlantic, and Lucent Technologies. Key U.S. Government players include the NSA, the NRL, and DARPA, whom we all recall funded the original Internet.

MONET is destined to unify all forms of electronic communications via color multiplexing within fiber-optic systems. Thirty years ago, this was impossible because scientists had not yet perfected the production of pure monochromatic light. Instead, they relied on traditional Fabry-Perot lasers that could not guarantee true monochromatic outputs. Thanks to the ingenuity of folks like Herwig Kogelnik, a new type of laser was developed known as a distributed feedback laser. These salt-grain-sized semiconductors are able to produce pure light due in part to a cascading effect that evenly distributes single photons across the laser. These lasers are an essential part of the MONET system that is currently in use within the United States.

Full-fledged civilian use is still in the future, but imagine the end result. Each and every home will have one fiber cable running to it. The tiny fibers within the cable will carry television, telephone, Internet access, and any other form of electronic data. In fact, all of these could fit on one piece of fiber because each source is assigned a separate color of the spectrum. Isn't this stuff amazing? We used to think spread-spectrum multiplexing was cutting-edge, but now we are actually using wavelengths of light to separate data.

Incidentally, Kogelnik has been making quite a stir in the telecommunications industry. Last June he received the IEEE Medal of Honor, and in December he was awarded the Marconi International Fellowship Award. Herwig Kogelnik is the Bell Labs Adjunct Photonics System Director. His work in holograms and optic filters led to the development of distributed feedback lasers. People like Kogelnik never lose their desire to learn or their ability to see beyond the confines of physicals laws. While some scientists are still busy deciding whether it is more correct to refer to light as a particle or a wave, other scientists are simply experimenting to see where science will take us next. Moral of the story: Keep learning, keep dreaming, and always challenge yourself. Oh, and be sure to keep your investors happy.

Fine Regards,

Chris La Morte
Managing Editor

mailto: letters@gernsback.com

The Telephone Circuits Gremlin Strikes Again

It appears that the "Telephone Circuits Gremlin" has struck again! In Fig. 3, page 36, in the article "Talk To The World For Free!" (**Poptronics**, November 2001), the connections to the RJ11 telephone jack, J5, are correctly shown going to terminals 3 and 4 (this is a 6-position jack). However, the colors shown are yellow and black—they should be red and green. The PCB layouts show the connections correctly as 3 and 4. I cannot determine from the PCB layout, and it is not clear on the schematic, but the positive supply voltage should be on the "green" terminal and the negative voltage on the "red" terminal. (Reversing of the polarity is usually not a serious problem, as most telephones will work with reversed supply voltage.)

A possibly more serious problem with the iPatcher circuit is the value of R19, 470 ohms. Resistor 19 is connected in series with the telephone used and with R18 across the 12-volt supply (but the voltage drop across R18 will be limited to about 0.6 volts by the parallel base-emitter junction of Q3.) With this amount of series resistance, the DC voltage and current to the telephone will be lower than if it were connected to a standard telephone line; and some phones may not work well.

Using about ten different telephones, I measured their current draw and the voltage across them when connected to my local phone line. The average values for them were about 7 volts at about 28 mA, so my "average" telephone has an effective internal DC resistance of about 250 ohms. From these values, I modified Ohm's Law to give an equation of the optimum series resistance, R, for any supply voltage, V:

$$R = \frac{V - 7}{0.028}$$

Using this equation, I got the value for R of 178.6 ohms for a supply voltage of 12. I have used a resistance of 200 ohms with a 12-volt supply, and it works fine. In the iPatcher, with a 470-ohm series resistor, the current for my "average" telephone would be about 16 mA, with a voltage at the telephone of about 4 V_{DC}. This current may result in poor operation of some telephones.

I would suggest that anyone having problems with the iPatcher should try using other telephones; a telephone that has a lower current draw may work better.
BILL STILES
Hillsboro, MO

Build A Better Mouse Trap

The circuit diagrams for "The Electronic Mouse Trap" in the December 2001 issue caught my eye for a couple of reasons. First, the value of R1 in Fig. 4 (the basic circuit) is shown as 47 ohms. The same resistor R1 in Fig. 5 (upgraded version) is shown as 47K. I think neither value is correct. I assume that transistor Q4 is being used as a saturated switch driving LED1, and R1 controls LED1 current. If the forward drop across LED1 is about 2V, and Vsat of Q4 is 0.5V, then the voltage drop across R1 should be

$$5V - 2V - 0.5V = 2.5V$$

If R1 is 47 ohms, calculated current would be 53mA, rather much for most LEDs. If R1 is 47K then calculated current would be 53µA, too little. My guess is that R1 should be 120–150 ohms, as most LEDs are rated for 20mA.

Second, both circuits have two 1N4004 diodes (D1 and D2) connected in parallel with the two solenoids to clamp flyback voltage when transistor Q3 turns off. I think diode D2 can be eliminated. Here is my thinking. The Jameco catalog shows the relays have a coil resistance of 155 ohms. Coil current is

$$12V/155 = .075\ A$$

for each relay. Diode 1 can easily handle the flyback currents of both relays.

$$(2 \times .075 = .15A).$$

Incidentally, for D1, any of the 1N400X diode series could be used, including the 1N4001 rated for 50V.
ERNIE WORLEY
via e-mail

KEEP IN TOUCH

We appreciate letters from our readers. Comments, suggestions, questions, bouquets, or brickbats ... we want to hear from you and find out what you like and what you dislike. If there are projects you want to see or articles you want to submit—we want to know about them.

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And don't forget to visit our Web site: *www.gernsback.com.*

Some Recommendations

I have been a long-time reader in the chain of publications leading up to **Poptronics**. I have learned much and have tried many of the circuits (most successfully). Accordingly, I have some recommendations.

Please educate us on the new on-board diagnostic systems in the automobiles (the OBDII system) and then provide us with some computer interface circuitry and software. The OBDII system appears to have many capabilities in knowing more about our car both for diagnostic and for real-time instrumentation (for us instrument nuts).

(Continued on page 54)

YESTERDAY'S NEWS

A PEEK INTO THE GERNSBACK ARCHIVES

1900

1910

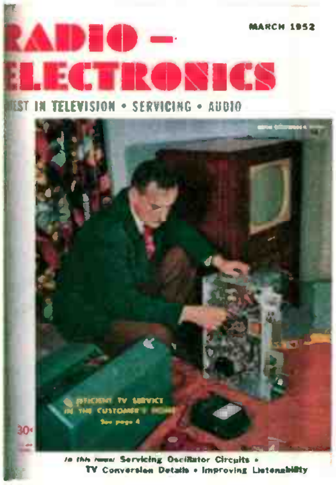
1930

1940

1952

Dateline: March 1952 (50 years ago)

Remember the days when the TV repairman actually came to the home to fix your TV? This issue of **Radio-Electronics** highlighted that experience, discussing the efficient service provided (now many of us actually consider it more efficient to just toss the set out and buy a new one!). Also mentioned in this edition was the expected profound impact that TV would have on the elections, indicating that TV "has a great destiny in providing an open forum in which every home has a front row seat in the discussion of national and international problems."



1960

1972

Dateline: March 1972 (30 years ago)

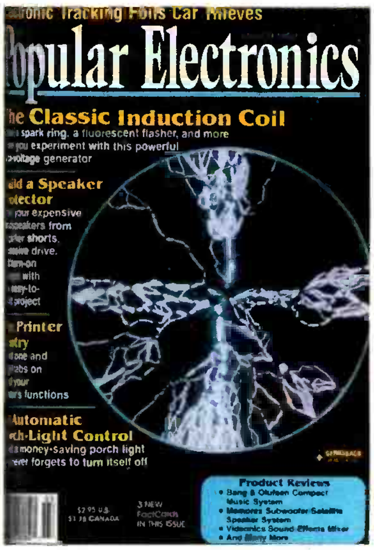
This special issue of **Radio-Electronics** covered the subject of 4-channel stereo. Topics included stereo-amplifier design and 4-channel matrix discs, add-on AGC for PA systems, and RCA vs. CBS. "Looking Ahead" featured the following reports: a proposal to switch the nation's television service to cable; video tape recorders/players that started at $1000, with rented video tapes that went for $3 a day (wow—some things actually don't change!); and automobile manufacturers that wanted to make tape players a standard feature in all cars.

1980

1992

Dateline: March 1992 (10 years ago)

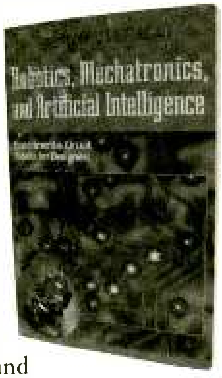
An automatic porch-light control, speaker protector, and printer sentry—these were just some of the construction projects featured in this issue of **Popular Electronics.** There was also a call-blocking system from RadioShack. An electronic version of the old dial lock, this gadget proved to be a useful weapon against those "900" numbers—usually teen-talk lines and con-artist psychics—that could rev up your phone bill into the triple digits. Also in the headlines: electronic vehicle-tracking systems that use specialized transmitters, Loran, and automated police dispatching to locate stolen cars.



2000

NEW LITERATURE

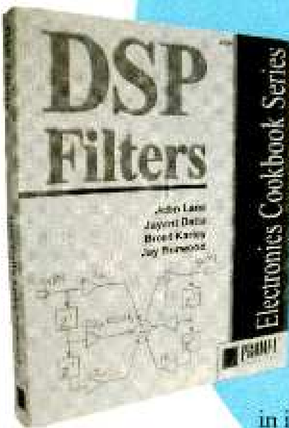
Robotics, Mechatronics, and Artificial Intelligence



by Newton C. Braga
Newnes, Butterworth-Heinemann
225 Wildwood Ave.
Woburn, MA 01801-2041
781-904-2500
www.newnespress.com
$29.99

Accessible to all enthusiasts at all levels, including students and amateur technology hobbyists, this book provides inexpensive and creative robotics projects. It covers a wide range of electronics disciplines, including interfacing with computers, home automation, mechanics, and more. The comprehensive project blocks make it possible for readers to pick and choose the circuit elements for individual robotic projects. From how to control a DC or stepper motor to instruction on creating moving robotic parts—this book covers it all.

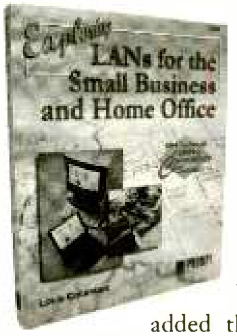
DSP Filters



by John Lane, Jayant Datta, Brent Karley, and Jay Norwood
Sams Technical Pubishing
5436 W. 78th St.
Indianapolis, IN 46268
800-428-SAMS
www.samswebsite.com
$39.95

Through the use of simplified tutorials and step-by-step instructions, this collection of audio projects breaks down the barrier of complex designs. The authors present the design formulas needed to build the digital equivalent of standard auto filters—low-pass, high-pass, band-pass, and band-stop—and also include the more specialized peaking and shelving filters. The projects that are presented were chosen for their potential interest, with special consideration of their usefulness in illustrating design concepts.

Exploring LANs For The Small And Home Office

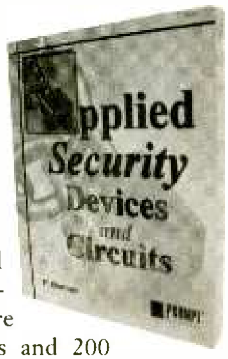


by Louis Columbus
Sams Technical Pubishing
5436 W. 78th St.
Indianapolis, IN 46268
800-428-SAMS
www.samswebsite.com
$39.95

What do you do when you've added that third computer to your growing office and want to share files, printers, and other resources? You may want to set up your own Local Area Network (LAN) to help you gain efficiency and save money. This text covers everything from the fundamentals of small-business and home-based LANs to choosing appropriate cabling systems. It also includes TCP/IP (Transmission Control Protocol/Internet Protocol) coverage, as well as protocols and layering.

Applied Security Devices and Circuits

by P. Benton
Sams Technical Pubishing
5436 W. 78th St.
Indianapolis, IN 46268
800-428-SAMS
www.samswebsite.com
$34.95

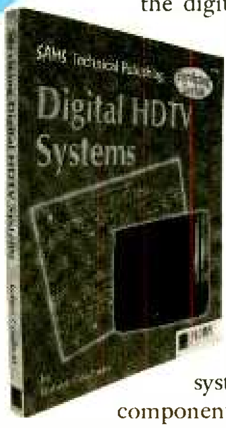


As security components have become user-friendly and affordable, more people are installing and building their own security systems. Do-it-yourself security devices are now buildable by anyone with a moderate electronics or electrical background. Applying proven electronics techniques, the authors present more than 100 applied security applications and 200 schematics and illustrations, including automobile security systems, basic alarm principles, and high-voltage protection.

Digital HDTV Systems

by Robert Goodman
Sams Technical Pubishing
5436 W. 78th St.
Indianapolis, IN 46268
800-428-SAMS
www.samswebsite.com
$34.95

By giving readers an overall view of how the digital HDTV system operates, the author provides explanations of HDTV circuit operations and functions. A practical tool for any technician meeting new challenges in the field of HDTV, this text covers the use of specialized test instruments, troubleshooting HDTV receiver problems, adjustments, alignments, three basic scanning systems, and other connected components.



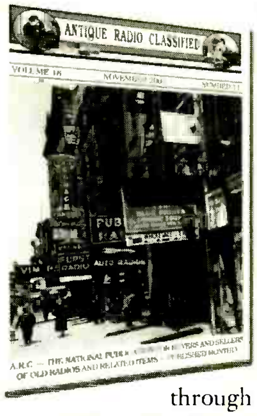
Electronics Components Catalog, #214

from Jameco Electronics
1355 Shoreway Road
Belmont, CA 94002
800-831-4242
www.jameco.com
Free

This 192-page catalog features thousands of ICs and other electronic components, tools, test equipment, and computer products. Used by engineers, educators, and service and repair techs, this catalog is a great source for finding leading-edge and hard-to-find items. Included are over 400 new products, among which are surface-mount ICS, PIC chips, and breadboards. There's also an inventory overstock sale on over 800 products.

Antique Radio Classified

by John V. Terrey
A.R.C.
P.O. Box 2
Carlisle, MA 01741
866-371-0512
www.antiqueradio.com
Free



Printed monthly for people involved in the hobby of radio collecting and restoring, this national publication strives to stimulate growth and interest through the buying, selling, and trading of radios and related items. This black-and-white periodical features articles, product reviews, auction reports, meeting notices, and many pages of classifieds. It also provides a forum for the exchange of ideas and information between fellow enthusiasts.

Coaxial & Fiber Optics Catalog

from Pasternack Enterprises
P.O. Box 16759
Irvine, CA 92623-6759
949-261-1920
www.pasternack.com
Free

This 200-page catalog offers an expansive list of coaxial and fiber optic products, including connectors, adapters, attenuators, switches, and tools. Detailed diagrams and descriptions accompany each product—complete specifications of electrical and mechanical properties, as well as information on interconnecting devices, are also provided.

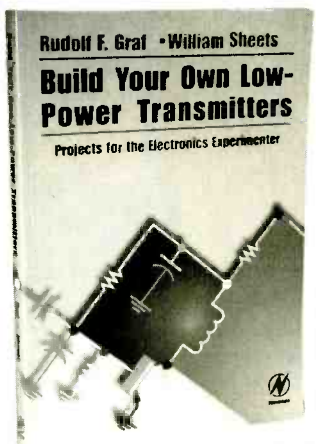
Home Automation Catalog Volume 47A

from Smarthome
17171 Daimler St.
Irvine, CA 92614
800-762-7846
www.smarthome.com
Free

Are you interested in having your home fully automated, as seen in science fiction movies? Can you imagine closing your drapes, unlocking your doors, and turning on your lights, all by remote control? You can operate almost anything in your home with an electronic system called X10, one of the products featured in this 100+-page, full-color catalog. Other products include home-security devices, sensors, home-theater systems, phone systems, and even automated plant care.

Build Your Own Low-Power Transmitters

by Rudolf F. Graf and William Sheets
Newnes, Butterworth-Heinemann
225 Wildwood Ave.
Woburn, MA 01801-2041
781-904-2500
www.newnespress.com
$39.95



Due to the recent change in FCC regulations, electronics experimenters are now legally allowed to discover the world of "pirate radio." Presented here are 20 low-power transmitter projects, designed particularly for the electronics hobbyists and radio experimenters. The authors cover the legal limits and particulars of using the equipment, as well as getting optimum performance. In addition, there is also a source list for locating the parts and kits needed to complete the projects.

GIZMO®

For more information go to page 80A

or e-mail: requests@berkshire-is.com

Taking It To The Streets

The *CDC-MA01* car stereo receiver ($349.95) plays MP3- and Windows Media Audio-encoded CDs, as well as audio CDs. Any portable audio device can be connected to the car audio system with the front-panel input jack. The head unit includes a built-in 200-watt amplifier rated to deliver 50 watts to four channels, a CD changer control, and a wireless steering-wheel-mounted remote control. One key feature is the motorized front panel that flips down to expose the CD slot and retracts when the ignition is off.

Aiwa America, Inc.; 800 Corporate Drive Mahwah, NJ 07430; 800-BUY-AIWA; *www.aiwa.com.*

CIRCLE 50 ON FREE INFORMATION CARD

Personal Warning System

In the wake of September 11 and the continuing anthrax threat, up-to-the-minute information is vital. *The Weather Alert 2000* ($59.95, plus $9.95/month subscription fee) uses a combination of satellite and 900-MHz Flex technologies to deliver urgent warnings from the National Weather Service in less than 90 seconds. That's not all—it also broadcasts National Attack Warnings and Civil Emergency Messages from the emergency management agencies, as well as news bulletins from the company's operations center. The desktop receiver can also be programmed to monitor distant locations, keeping track of conditions at vacation homes or travel destinations.

Page Update, Inc., 5590 Nolenville Rd., Nashville, TN 37211; 800-743-4989 or 615-333-5880; *www.pageupdate.com.*

CIRCLE 51 ON FREE INFORMATION CARD

Broadband DVR

ReplayTV 4000, the first Digital Video Recorder (DVR) with broadband connectivity, lets users share recorded shows between ReplayTVs and even send those shows to friends via the Internet. The device's Ethernet port allows you to connect two ReplayTV 4000 units, transfer photographs from your PC to your TV, and even set up recordings from any computer with an online connection. Commercial Advance provides ad-free playback of your recordings. The unit offers 480P progressive output for HD-ready TVs, and an optical digital audio output. Prices range from $699 for the model 4040, with 40 hours of recording time, to $1999 for the 320-hour model 4320.

SONICblue; 2841 Mission College Blvd., Santa Clara, CA 95054-1838; 877-737-5298 or 408-588-8000; *www. sonicblue.com.*

CIRCLE 53 ON FREE INFORMATION CARD

Boxed Set

Packing the performance and capabilities of high-end separates into a bundled all-in-one home theater system, the *HTS-L5* ($1300) includes a receiver, DVD player, and six speakers. The TX-L5 receiver provides DTS, Dolby Digital, and Dolby Pro Logic II decoding; an AM/FM tuner; and nine DSP soundfields. The matching DV-L5 DVD player also plays MP3-encoded CDs, CD-Rs, CD-RWs, and video CDs. The SKS-105 speaker package features a pair of slim towers, two surround speakers, a center-channel speaker, and the SKW-50 subwoofer with 60-watt amplifier.

Onkyo U.S.A. Corp., 18 Park Way, Upper Saddle River, NJ 07458; 800-229-1687 or 201-785-2600; *www.onkyousa.com.*

CIRCLE 52 ON FREE INFORMATION CARD

Projection: Affordable

The world's smallest, lightest home-theater projector, the *Piano HE-3100* ($2999), can fill an 80-inch diagonal 16:9 screen from a distance of less than ten feet or a 36-inch diagonal from just four feet away. The table-top projector uses Texas Instruments' DPL technology, a built-in Silicon Image SIL 503 digital video processor/progressive scanning converter, and a special motion-compensation feature to produce DVD-quality images with reduced artifacts. Measuring 9.3 × 7.8 × 3.6 inches and weighing 4.4 pounds, the Piano comes in silver, black, white, red, or blue.

PLUS Corporation of America, 80 Commerce Drive, Allendale NJ 07401; 800-289-7587 or 201-818-2700; *www.PlusHome Theater.com*

CIRCLE 54 ON FREE INFORMATION CARD

GIZMO®

Where's The Dish?

Replacing the familiar round satellite dish, the *PASSPort HDBS-2000* ($299.95) is the first flat-panel satellite TV antenna for home use with DirecTV and DishNetwork systems. The 16 × 20 × 1.1-inch antenna uses phased-array technology, in which many small reception elements work together to form a strong signal when aimed at a satellite. No assembly is required, and the dual-LNB unit can be mounted on the wall or roof or on a pole.

SatCom Electronics, Inc., 13400-B Danielson St., San Diego, CA 92064; 858-486-6600; *www.satcomweb.com.*

CIRCLE 55 ON FREE INFORMATION CARD

LCD TV

The *AQUOS* 20-inch LCD flat-screen television ($3299) uses proprietary "Black TFT" technology—a low-reflection coating with anti-glare treatment—for a bright picture and vivid colors even in strong light conditions. Slightly more than two inches thick, the TV comes with a stand and carrying handle that make it easy to transport and set up anywhere. It offers a 160-degree viewing angle and stereo sound through two built-in speakers.

Sharp Electronics Corp., Sharp Plaza, Mahwah, NJ 07430; 877-388-SHARP; *www.sharp-usa.com.*

CIRCLE 57 ON FREE INFORMATION CARD

Classy Clicker

The *Pronto Pro TSU6000* ($999) provides full IR/IF control over even the most complex, multi-room home-entertainment systems. With a database of codes for more than 500 brands in 17 product categories, it can be set up to control a component in seconds. The remote can also learn codes for devices not in its database. *Pronto Edit Software* (included) synchronizes the remote with a PC, making it easy to create and edit macros, customize menus, and arrange the virtual buttons on the color touchscreen.

Philips Consumer Electronics, 64 Perimeter Center East, Atlanta, GA 30346; 770-821-2400 or 800-531-0039; *www.philips.com.*

CIRCLE 56 ON FREE INFORMATION CARD

Nine-Band Radar Detector

The *ESD 9850* ($249.95) offers nine bands of detection capabilities. Among them are the patented Safety Alert and Strobe Alert warning systems. These systems provide warnings of approaching emergency or construction vehicles and other potential road hazards and of strobe-equipped emergency vehicles that change traffic signals, respectively. The sleekly curved device is equipped with LaserEye 360-degree detection, Voice Alert verbal warning system, and an electronic compass.

Cobra Electronics Corp., 6500 West Cortland St., Chicago, IL 60707; 773-889-3087; *www.cobra.com.*

CIRCLE 58 ON FREE INFORMATION CARD

Mega CD Storage

Need more storage for your discs? The *CDW-264 Classic CD Wallet* ($54.99) holds 264 CDs in a portable, album-style case with an innovative strap system that allows pages to lay flat for easier access. The durable padded case is resistant to heat and moisture and features a sturdy carrying handle.

Case Logic, Inc., 6303 Dry Creek Parkway, Longmont, CO 80503, Attn: Customer Service; 800-925-8111; *www.caselogic.com.*

CIRCLE 59 ON FREE INFORMATION CARD

PC GIZMO®

PC Sound Morpher

Kids can record their voices and other sounds and then mix and change them in surprising ways with the IntelPlay *Computer Sound Morpher* ($49). The translucent blue peripheral comes with software and headphones. It features pre-set sounds, cool filters such as "echo" and "ballpark," and various morphing tools. Children can type in messages for the computer to say back to them and can then create silly animations to go along with their recordings.

Intel Corp.; 800-538-3373 or 916-377-7000; *www.intelplay.com.*

Virtual Rock Star

Forget air guitar. *MusicPlayground On Stage* uses virtual instruments—plug-and-play USB peripherals—to simulate real instruments. Even if you have no musical training, the CD-ROM lets you take over the guitar, bass, or drum parts of your favorite songs. Plug in your virtual instrument and start jamming with the band. All three packages include a V-Pick virtual guitar (or bass) pick, a CD with *MusicPlayground Player* software, and direct access to the company's online music jukebox. The $29.95 Concert Edition in-cludes the V-Pick and 25 songs; add a virtual drum for $19.95. The $69.95 Band Edition gets you the V-Pick, drum kit, and 50 songs. A special Beatles Edition ($39.95) provides 25 songs from the Fab Four.

MusicPlayground, Inc., 978-688-8800; *www.MusicPlayground.com.*

Wireless USB Client Device

The *Orinoco USB Client* is the first USB wireless networking radio to receive both the Wi-Fi and the USB Compliance Test certificates. The plug-and-play device allows high-speed wireless connectivity to be easily added to desktop computers in the home, small business, or corporation. It provides a wireless network connection of up to 11 Mb/s.

Agere Systems; 866-ORiNOCO; *www.orinocowireless.com.*

Multi-Platform Printer

Printing 15 pages per minute, the *HL-1470N* personal laser printer ($499) boasts a fast first-page-out time of less than 15 seconds. Output quality of 1200 × 600 dpi ensures sharp, clear printing of both text and graphics. The printer has 8MB memory, expandable to 36MB, and offers USB and parallel interfaces as well as a 10/100 BaseT Ethernet card. It supports Windows 95 through 2000; NT4.0; and Apple iMac, iBook, and G4.

Brother International; 800-276-7746; *www.brother.com.*

Web Mice

The *GE Web Mouse* ($18.95)—available in translucent blueberry (pictured), grape, lime, and watermelon—makes it easier to navigate around your Windows computer screen. Using 800-dpi resolution technology, the Web Mouse requires only half the distance for every movement compared to traditional 400-dpi mice. A programmable third button provides easy vertical and horizontal scrolling.

Jasco Products; 800-654-8483; *www.jascoproducts.com.*

Gizmo is published by Gernsback Publications, Inc., 275-G Marcus Blvd., Hauppauge, NY 11788. Senior Writers: Christopher Scott and Teri Scaduto.

Business Buzz

BROADENING BROADBAND
Sony and AOL Time Warner have agreed to work together to develop easy-to-use home networking technologies. The plan calls for the development of broadband home-networking gateway technologies to access broadband services from multiple PCs and other devices simultaneously and to allow stored content to be shared among devices, with proper copyright management. The companies envision a new Internet browser that provides consistence and convenience on networked consumer products—first in Sony gear and then for other manufacturers. They will also explore whether AOL will offer access service for Sony's networked consumer devices in the U.S.

CLASSROOM MONOPOLY?
Microsoft's proposal to settle a lawsuit by giving under-funded schools more than a billion dollars worth of software and services has some people asking: Just who would most benefit from such an arrangement—the schools and students or the corporation itself? The Computer and Communications Industry Association (which represents Microsoft rivals) and Apple Computer have spoken out against the proposed arrangement, charging that supplying schools with free Windows products would effectively eliminate competitors' products. Ironically, the lawsuit tentatively being settled with gratis software was over Microsoft's alleged Windows monopoly, which users claimed forced them to overpay for the operating system.

HOLLYWOOD VICTORY
The Manhattan U.S. Court of Appeals struck down a claim by Eric Corley, a Long Island hacker, that the First Amendment gave him the right to post a DVD-decryption code over the Internet. It upheld as constitutional the 1998 law that prohibits digital piracy and the distribution of software for bypassing the codes used to protect digital movies, music, and books. While recognizing that the DeCSS computer code could be considered legitimate speech, the Appeals Court noted, "the capacity of a decryption program to accomplish unauthorized—indeed, unlawful access to materials in which the plaintiffs have intellectual property rights must ... limit the scope of its First Amendment protections." Corley, who publishes *2600-The Hacker Quarterly* and *2600.com*, plans to appeal his case to the U.S. Supreme Court.

Back to the FutureTruck

Shown here participating in the 2001 Emissions Event is the Michigan Tech entry.

People who drive them love them. The rest of us despise the gas-guzzling, road-hogging beasts. Whether you love 'em or hate 'em, there's no question that sport utility vehicles are not environmentally friendly. SUVs and light-duty trucks make up more than half of all new vehicle sales. Less energy efficient than cars, the vehicles contribute to increased greenhouse gas emissions and dependence on foreign oil.

A Greener SUV

FutureTruck is an ongoing, four-year program that tackles the SUV's energy-related issues in a unique way. In an upscale version of "Junkyard Wars" sponsored by the U.S. *D*epartment *o*f *E*nergy (DOE) and major automotive manufacturers, teams of students from 15 top North American universities compete to create a "greener" SUV. Their goal is to re-engineer a conventional SUV into a *l*ow-*e*missions *v*ehicle (LEV) with at least 25% higher fuel economy—without sacrificing performance, utility, safety, or affordability. The competition consists of a series of events in which student-modified FutureTruck vehicles are evaluated in technical performance categories (acceleration, trailer towing, and off-road handling), static design (consumer acceptability, engineering design review, and oral technical presentation reports), and environmental goals (emissions and fuel economy). Points are rewarded in each event category; the highest overall score wins the competition.

General Motors was the headline sponsor for the 2000–2001 segments of the competition when the student teams worked on Chevrolet Suburbans. Ford is partnering with the DOE for the 2002–2003 events where the teams will be modifying Ford Explorers. The DOE's Argonne National Laboratory provides management and technical and logistical support. Additional FutureTruck support comes from 11 private and public organizations.

Back To The Past

The competition's first two years saw some impressive results. In 2001, for instance, the students achieved a 13% improvement in on-road fuel efficiency and a 25% reduction in *g*reen*h*ouse *g*as (GHG) emissions over stock Chevrolet Suburbans—without compromising acceleration time or trailer-tow capability.

The *U*niversity of *C*alifornia (UC), Davis, and the *U*niversity of *W*isconsin (UW), Madison, were neck and neck during most of that FutureTruck competition. While UW-Madison garnered many of the individual events awards, UC-Davis walked off with the first place award. The Emissions Event turned out to be the deciding event. Here the vehicles must demonstrate simultaneous control of regulated pollutants, including non-methane hydrocarbons, carbon monoxide, oxides of nitrogen, and *par-*


The Idaho FutureTruck goes through its paces in the Acceleration Event.

ticulate *m*atter (PM). UC-Davis scored 80 points with a 1.9-L Saturn running on reformulated gasoline. Using a 2.5-L Land Rover TD5 engine fueled by biodiesel, UW-Madison' hybrid vehicle had low overall emissions, but a PM level too high to earn any points in this event. First place in the Emissions Event went to the University of Maryland team, whose vehicle—running on a fuel mix of 85% denatured ethanol and 15% gasoline (E85)—was rated a *S*uper *U*ltra-*L*ow *E*missions *V*ehicle (SULEV).

UW-Madison did take the On-Road Fuel Economy Event, measured over a route that included stop-and-go, urban, and highway driving segments with prescribed speed limits. The total distance traveled divided by the amount of energy (fuel and electricity) used determined the fuel economy of the vehicle. The Madison team achieved a fuel economy of 28.1-mpg gasoline-equivalent, a 62% improvement over the stock vehicle's performance of 17.3 mpg.

Other events included an Off-Road "obstacle course" and a quarter-mile-straightaway acceleration test.

Future FutureTrucks

In the next phase of the competition, Ford will supply each team with new Explorers and engineering consulting help. The company will also donate almost $200,000 in seed money and cash prizes. FutureTruck 2002 will be held June 11–21, 2002, at three sites: Ford's Arizona Proving Ground in Yucca, the California Air Resources Board in El Monte, and the California Motor Speedway in Fontana. The teams will then travel to Los Angeles for a vehicle display and awards ceremony.

"Ford's commitment to dramatically increase SUV fuel economy for 2005 and beyond is a huge ongoing challenge and we're looking for new, creative ideas," said Bob Himes, engineering director for Ford Outfitters sport utilities. "FutureTruck presents many opportunities for Ford Motor Company, not the least being the cultivation of engineering technology and talent." PT

Anthrax-Scrubbing Bubbles

A decontamination formulation developed at the National Nuclear Security Administration's Sandia National Laboratories was one of the products that helped rid Capitol Hill buildings of anthrax last autumn. The "decon foam" was used in the Hart Senate Office Complex, the Dirkson and Ford Congressional offices in Washington, and in contaminated Capitol Hill mailrooms.

A five-year research project resulted in the development of the formula, a mixture that includes ordinary household substances such as those found in hair conditioners and toothpaste. Applied as a liquid spray, mist, fog, or foam, it neutralizes a wide variety of chemical and biological agents in minutes. It is also non-toxic, non-corrosive, and environmentally friendly. In lab tests at Sandia, the foam destroyed simulants of anthrax and chemical agents, vegetative cells, toxins, and viruses. Multiple independent lab tests and military trials found the decon foam to be effective against viable anthrax spores and chemi-

Sandia researcher and decon foam co-developer Maher Tadros demonstrates the chem-bio decontamination formulation that helped rid Washington D.C. buildings of anthrax contamination.

Research Notes

IT'S MaGIC!

Gibson Labs, the research division of Gibson Guitar, has applied the digital technology developed for computer networking to audio equipment. The result is MaGIC, a.k.a., *M*edia-*a*ccelerated *G*lobal *I*nformation *C*arrier, a new connectivity protocol that transforms a standard CAT-5 Ethernet cable into a "super cable" capable of carrying more data faster and farther. The new Digital Media distribution standard allows audio, video, and control information to be carried over an Ethernet cable with increased bandwidth and higher speed. Much longer signal lengths with no signal degradation will be possible; and there are potential applications in live concerts, high-resolution audio/video distribution, home automation, commercial wiring installations, and telecommunications products.

X-RADIATION RULE CHANGES?

The *C*onsumer *E*lectronics *A*ssociation (CEA) has filed with the *F*ood and *D*rug *A*dministration (FDA), asking to simplify the testing and certification procedure by which television manufacturers confirm their compliance with established x-radiation emission requirements. With the use of modern transistorized circuitry, the level of x-radiation emissions from television sets has not approached that of naturally occurring background radiation (about one-fifth of the FDA's limit) in the last 20 years. Michael Petricone, vice president of CEA's Technology Policy Department, said, "During the last two decades, television set manufacturers have voluntarily reduced x-radiation emissions to levels well below the FDA's limit, and it is time the regulatory process caught up to the technology."

HEAT-ACTIVATED EPOXY

A research team at Sandia National Laboratories has developed a temperature-dependent removable epoxy adhesive that bonds at low temperatures and melts at 90° to 130° C (about 190° to 260° F). When heated, the bond only needs minimal force to break, reducing the chance of damaging the pieces during separation. The adhesive, which looks and feels like a large rubber band when unheated, will rebond at room temperature—retaining the ability to bond and unbond a number of times. The removable adhesive has been successfully applied to numerous metals and to some foams and polymers.

Researcher Tadros displays the non-toxic foam that's also environmentally friendly.

cal warfare agents.

Sandia licensed the right to commercialize the chem-bio formulation to Denver-based Modec, Inc. and to *E*nviro*F*oam *T*echnologies (EFT) of Huntsville, AL. EFT's version of the decon foam was used to support the EPA's clean-up effort on Capitol Hill. PT

"Un-generated" Electricity

Associate Professor Peter L. Hagelstein of MIT's Department of Electrical Engineering and Computer Science and his colleague, Dr. Yan Kucherov of ENECO, Inc., have invented a form of semiconductor technology that could allow electricity to be produced cheaply and efficiently—without using a turbine or similar generator. While the researchers aren't the first to try to directly convert heat to energy, previous attempts have resulted in inefficient devices that don't produce enough electricity. This unit is twice as efficient as its closest commercial competitor. "That such good results were obtained in the first generation of the new device technology...indicates that the general approach has great promise for improved performance in more mature implementations," said Hagelstein.

Based on thermionics, this process traces its roots back to the turn of the 20th century with the basic vacuum tube. In a high-temperature vacuum tube, two parallel conductive plates (cathode and anode) are separated by a vacuum gap. Electrons boiled off the cathode, crossed the gap, and were absorbed into the colder anode. As the electrons move "uphill" against the electric field in the gap region, heat is converted to electricity. Because "vacuum gap" designs suffered from high manufacturing costs and operating temperatures above 1000° C (about 2000° F), the technology has been limited to use in nuclear-powered converters in space probes, satellites, and special military systems.

Hagelstein and Kucherov essentially replaced the traditional vacuum gap with a multi-layer semiconductor structure. They demonstrated two basic enabling physical mechanisms for implementation. By carefully choosing the material, scientists at ENECO created highly efficient solid-state conversion devices. These "thermal diodes" will operate from 200° to 450° C—typical temperatures for waste heat and concentrated solar radiation.

Among possible applications, the new technology might recover waste heat from automobiles and power plants. Heat lost through engine exhausts could be captured and converted into electricity to augment the vehicle's electrical and air-conditioning systems. It could also play a major role in the primary generation of electrical power. The technology itself is environmentally friendly—thermal to electric energy production generates no pollution—although some of the materials used in the first generation of devices are toxic. The research, which is sponsored by ENECO with additional support from the Defense Advanced Research Projects Agency, is currently focusing on optimizing materials in the thermal diodes. PT

Transistor Innovation

Intel researchers have developed a unique transistor structure with new materials—a dramatic improvement not only in transistor speed, but also in power efficiency and heat reduction. "Smaller and faster just isn't good enough anymore," said Gerald Marcyk, director of components research, Intel Labs. "Power and heat are the biggest issues for this decade. What we are doing with our new transistor structure is helping make devices that are extremely power efficient, concentrating electrical current where it's needed." As hundreds of millions—and even billions—of smaller and faster transistors get packed onto a thumbnail-sized piece of silicon, limiting power consumption and the amount of heat generated in the processor core becomes a challenge.

New chip technology developed by Intel helps chips run cooler and increases speed and efficiency.

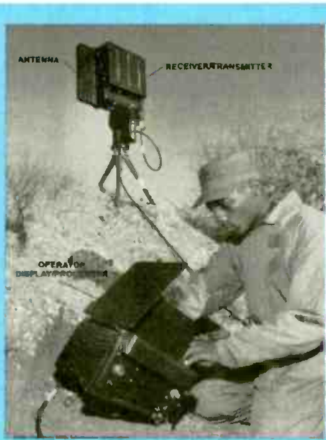
The new device is called the Intel TeraHertz transistor because its transistors can switch on and off more than one trillion times per second. (It would take a person more than 15,000 years to turn a light switch on and off a trillion times.) The TeraHertz represents two significant improvements over current transistor design: a "depleted substrate transistor" and a new material called a "high k gate dielectric." A depleted substrate transistor is a new type of CMOS device in which the transistor is built in an ultra-thin layer of silicon on top of an embedded layer of insulation. This ultra-thin layer is fully depleted to create maximum drive current when the transistor is turned on, allowing faster on/off switching. When the transistor is turned off, the thin insulating layer keeps current leakage to a minimum. The TeraHertz has 100 times less leakage than traditional silicon-on-insulator designs.

The smallest and fastest transistors introduced recently have all had gate dielectrics made of atomically thin layers of silicon dioxide, and leakage through these layers has become the major

➤Homeland Radar Defense

Telephonics Corp. recently demonstrated its Ground Surveillance Radar (GSR) system to U.S. Senators Chuck Shumer and Hillary Clinton and Congressman Steve Israel (all New York Democrats) as a possible defense against future terrorist acts. Israel is a member of the Democratic Homeland Defense Task Force.

The lightweight, low-power radar system can be deployed in less than five minutes to protect borders and high-value targets. Little training is required to set up and effectively operate the system. The GSR can easily establish portable, fixed or highly mobile surveillance operations around potential targets in sensitive areas in all weather conditions, night or day. This device gathers, processes, and disseminates critical intelligence data quickly and reliably. The system can protect water reservoirs, nuclear and conventional power plants, airport facilities, and bridges. It is estimated that it would take three or four of the $200,000 devices to monitor a power plant. PT



Protecting the homeland or any land, the lightweight, portable GSR system can be deployed easily and quickly.

source of power consumption. The "high k gate dielectric" replaces silicon dioxide as the "gate-dielectric" and reduces gate leakage by more than 10,000 times. Using "atomic layer deposition," the material is grown in layers only one molecule thick at a time.

The TeraHertz is expected to enable powerful new applications such as real-time voice and face recognition; computing without keyboards; and more compact, higher-performance computer devices with longer battery life. PT

Doubly Strange Brew

Researchers at the DOE's Brookhaven National Laboratory have brewed up a significant number of "doubly strange nuclei," or nuclei that contain two strange quarks. Helping scientists explore the forces between nuclear particles and, especially, within "strange" matter, studies of these nuclei may contribute to a better understanding of neutron stars. Such stars are the only place in the universe where scientists believe such strange matter exists in a stable form. These super-dense remains of burnt-out stars are believed to contain large quantities of strange quarks.

Fifty physicists collaborated on the project, which created 30 to 40 of the doubly strange nuclei—enough of them "to begin a study using statistical techniques," according to team member Adam Rusek.


The research team (front, from left) of Adam Rusek and Robert Chrien, and (back, from left) Sidney Kahana, Philip Pile, and Morgan May pose in and around the AGS with the cylindrical detector system for the doubly strange nuclei experiment. (Photo courtesy of Brookhaven National Laboratory.)

One of Brookhaven's particle accelerators, the Alternating Gradient Synchrotron (AGS), was used to aim the world's most intense proton beam at a tungsten target. The collision creates particles from which the scientists separate out a beam of negatively charged kaons, each composed of one "strange" quark and one "up" antiquark. The negative kaons then strike a beryllium target and interact with its protons. In the process, some of the energy is converted into new strange quarks and strange antiquarks, which then regroup to form a variety of particles—some of which continue to interact. Occasionally, the result is a structure that contains a proton, a neutron, and two lambda particles—each composed of one "up," one "down," and one strange quark. The double-lambda structure, with its two strange quarks, is the doubly strange nucleus.

It isn't easy to detect the formation of this strange species—in fact, it's a bit like looking for "a subatomic needle in a particle-soup haystack." Many other species are produced in the collisions, and scientists can't see the double-lambda structure directly. They have to look for pions, subatomic particles emitted by the lambdas as they decay. Two pion decay signals, at very specific energies, indicate a nucleus with two lambdas.

Sophisticated computers and careful analysis narrowed the search from 100 million potentially interesting events to 100,000 in which two strange quarks were produced to the 30 or 40 in which the two strange quarks existed for an instant inside the same nucleus. PT

BUDGET PROJECT AND COMPUTER BOOKS

☐ **BP294—A Concise Introduction to Micro-soft Works $6.99.** You can use the word processor to your advantage to type, edit, print and save documents. This book explains how Works can be used to build up simple spreadsheet examples, edit them, save them, print them and retrieve them. It informs you how to create simple macros, and to simplify long repetitive tasks and to customize the program to your own needs.

☐ **BP350—Electronic Board Games $6.99.** Twenty novel electronic board games that you can build from the plans in this book. Whether you are interested in motor racing, searching for buried treasure on a barren island or for gold in Fort Knox, spinning the wheel of fortune, or doing a musical quiz—there is something for you to build and enjoy!

☐ **BP378—45 Simple Electronic Terminal Block Projects $6.99.** 45 easy-to-build electronic projects that can be built by an absolute beginner. Projects are assembled on terminal blocks using only a screwdriver and other simple hand tools. No soldering is required.

☐ **BP432—Simple Sensor Terminal Block Projects $6.99.** This book is the next logical step from the above book (BP378), by the same author. This is an *open sesame* to the practical world of electronics for youngsters or beginners.

☐ **BP367—Electronic projects for the Garden $6.99.** Electronics enters the Garden! Gardeners can build simple gadgets to promote success where the elements work against you. Some of the projects are: over/under temperature monitoring, dusk/dawn switching, automatic plant watering, warming cables, etc.

☐ **BP368—Practical Electronics Musical Effect Units $6.99.** There is a constant hullabaloo for musical effects projects by the hobbyist community. This book provides practical circuits for several projects that range in complexity and are sure to work. All the circuits are easy to build and use readily-available parts.

☐ **BP385—Easy PC Interfacing $6.99.** The built-in ports in your PC provide an easy and hassle-free way of interfacing your circuits. This book provides useful PC add-on circuits including the following: Digital input/output ports; analog-to-digital and digital-to-analog converters; voltage and current measurement circuits; resistance and capacitance meters, temperature measurement interface, biofeedback monitor, and many other useful interfaces.

☐ **BP396—Electronic Hobbyists Data Book $7.99.** This book contains details of a modern five-band resistor code or an old color code for a ceramic capacitor, the formula for parallel resistance, and basic data on an NE5534AN operational amplifier.

☐ **BP129—An Introduction to Programming the ORIC-1 $2.99.** This book has been written for readers wanting to learn more about programming and how to make best use of the ORIC-1 microcomputer's many powerful features. Most aspects of the ORIC-1 are covered, the omissions being where little could usefully be added to the information provided by the manufacturer's own manual. Starting with simple commands and programs, the more complex topics such as animated graphics and using sound commands are introduced.

☐ **BP131—Micro Interfacing Circuits – Book 2 $3.99.** This book is intended to carry on from where Book 1 left off. It is primarily concerned with practical applications beyond the parallel or serial interface to the microprocessor. It is about "real world" interfacing including such topics as sound and speech generators, temperature and optical sensors, motor controllers etc. Like Book 1 the subject is not treated in a purely theoretical manner.

☐ **BP298—Concise Intro to the Macintosh System and Finder $5.99.** This book explains: The System and Finder, what they are and what they do; how to use the System and Finder to manipulate disks, files and folders; configuring and printing files from the Finder; getting the most from the system utility programs; and running MultiFinder.

☐ **BP316—Practical Electric Design Data $7.99.** A comprehensive ready-reference manual for electronic enthusiasts with over 150 practical circuits. It covers the main kinds of components (from pig-tail leads to surface mount), pinouts, specs and type selection. Basic units are defined and most used formulae explained. Five additional sections are devoted to circuit design, covering analog, digital, display, radio and power supply circuits.

☐ **BP345—Getting Started In Practical Electronics $6.99.** This book provides basic essentials for the builder and 30 easy-to-build fun projects with which every experimenter should toy. Printed-circuits designs are included to give your project the professional touch.

☐ **BP451—Troubleshooting Your PC Printer $8.99.** Explains the different printer types, their suitability for different tasks, the costs of running them, how to connect them and get the driver software running and, of course, what is most likely to go wrong and what you can do for yourself. Most important of all, it warns you of what you should quite definitely NOT try to do for yourself.

☐ **PCP112—Digital Electronics Projects $10.99.** Contains 12 digital electronics projects suitable for the beginner to build with the minimum of equipment—from instrumentation to home security, and a few "fun" projects too. With one exception, all projects are battery powered, and therefore, are completely safe for the beginner or young constructor.

☐ **PCP107—Digital Logic Gates and Flip-Flops $10.99.** This book seeks to establish a firm foundation in digital electronics. It is for the user who wants to design and troubleshoot digital circuitry with full understanding of the principles. No background other than a basic knowledge of electronics is assumed.

☐ **BP317—Practical Electronic Timing $6.99.** This book provides the time measurement theory and backs it with a wide range of practical construction projects. Each project has how-it-works theory and how to check it for correct operation.

☐ **BP325—A concise User's Guide to Windows 3.1 $6.99.** Understand what hardware specification you need to run Windows 3.1 successfully, and how to install, customize, fine-tune and optimize your system. Get into understanding the Program Manager, File Manager and Print Manager. Tips on the word processor, plus how to use Paintbrush. More on the Cardfile database with its auto-dial feature, Windows Calendar, Terminal, Notepad, etc.

☐ **BP332—TTL Digital ICs $6.99.** Logic circuits are now part of everyday life, and practically every house is now equipped with gadgets that contain digital circuits. TTL logic integrated circuits are widely regarded as the "standard" range of digital devices.

☐ **PCP120—Multimedia on the PC! $14.95.** Multimedia can do lots of nice things! This 184-page book helps you create your own multimedia presentation. Multimedia applications by people like you can revolutionize educational and business applications as well bring more fun, fun, fun into your leisure computer activities.

☐ **BP404—How To Create Pages for the Web Using HTML $7.99.** HTML is the language used to create documents for Web browsers such as Mosaic, Netscape and Internet Explorer. These programs recognize this language as the method used to format the text, insert images, create hypertext and fill-in forms. HTML is easy to learn and use. This book explains the main features of the language and suggests some principles of style and design. Within a few hours, you can create a personal Home Page, research paper, company profile, questionnaire, etc., for world-wide publication on the Web.

☐ **BP411—A Practical Introduction to Surface Mount Devices $6.99.** This book takes you from the simplest possible starting point to a high level of competence in working with Surface Moint Devices (SMD's). Surface mount hobby-type construction is ideal for constructing small projects. Subjects such as PCB design, chip control, soldering techniques and specialist tools for SMD are fully explained. Some useful constructional projects are included.

☐ **BP379—30 Simple IC Terminal Block Projects $6.99.** Here are 30 easy-to-build IC projects almost anyone can build. Requiring an IC and a few additional components, the book's 'blackbox' building technique enables and encourages the constructor to progress to more advanced projects. Some of which are: timer projects, op-amp projects, counter projects, NAND-gate projects, and more.

☐ **BP304—Projects for Radio Amateurs $5.99.** Short wave radio is a fascinating hobby. One of the main attractions for many short wave enthusiasts is tinkering with different aerials and gadgets to get the best performance from their installation. This book describes a number of electronic circuits which can be used to enhance the performance of most short wave radio systems.

☐ **ETT1—Wireless & Electrical Cyclopeia $4.99.** Step back to the 1920's with this reprinted catalog from the Electro Importing Company. Antiquity displayed on every page with items priced as low as 3 cents. Product descriptions include: Radio components, kits, motors and dynamos, Leyden jars, hot-wire meters, carbon mikes and more.

☐ **BP76—Power Supply Projects $3.99.** Presents a number of power-supply designs including simpled unbiased types, fixed voltage-regulated types and variable voltage stabilized designs. All are low-voltage types intended for use with semiconductor circuits. Apart from presenting a variety of designs that will satisfy most applications, the data in this book should help the reader to design his own power supplies. An essential addition to the experimenters electronics library.

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RAF Electronic Hardware is offering a free *Sampler Kit* to anyone who visits their Web site mentioned below. The kit contains assorted electronic hardware items, including a variety of standoffs, captive panel screws, shoulder screws, thumbscrews, jack screws, washers, and handles. Their online catalog, which offers an extensive inventory of electronic hardware with complete specifications, is also available free.

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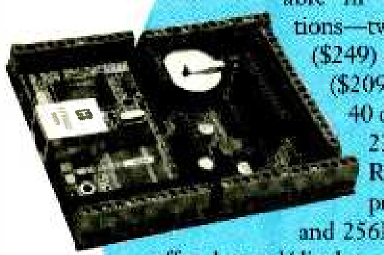

The *BL2100 Smartcat* is a single-board computer that is available in four configurations—two with Ethernet ($249) and two without ($209). All models have 40 digital I/O, three RS-232/485 serial ports, a Rabbit 2000 microprocessor, 128K SRAM, and 256K Flash. Both versions offer keypad/display options—in one small package. Perfect for embedded control and data acquisition, the BL2100 series provides comprehensive, integrated control capabilities. The *Smartcat* can also remotely monitor and supervise other programmable systems.

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The *Radiation Monitor Model 30314-75* ($339.95) indicates radioactivity via easy-to-read analog meters; and it offers a red light count, anti-saturation circuitry, and an audible beeper. The detector features an uncompensated, halogen-quenched, 1.5–2.0 mg/cm2 mica end window. It detects alpha down to 2.5 Me4, gamma and X-rays down to 10 Ke4, and 50 Ke4 beta at 35% efficiency—all through the sensitive end window.

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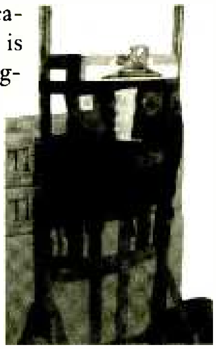
ToolCaddie



Intended for industrial applications, the *ToolCaddie* ($19.95) is made of tough nylon and long-lasting velcro with durable buckles. The carrier has a universal 8-point attachment system that will fit any type of hand-truck. Its five different-sized pockets accommodate all types of tools, from clipboards and tape guns to felt pens and utility knives.

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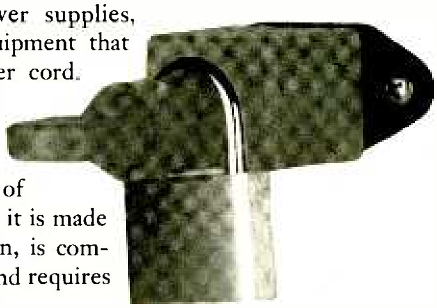
Lockout System



Equipment fitted with the IEC 320 input-power connector can be secured using the *Lockout 320* ($10.25). This security device will fit most computers, test instruments, power supplies, monitors, and lab equipment that use a removable power cord. Featuring an elastomeric nose that bulges to firmly grip to the interior surfaces of the connector housing, it is made of durable plastic nylon, is compact and lightweight, and requires no tools to apply.

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REID GOLDSBOROUGH

mailto: digitaldomain@gernsback.com

People-Friendly Technology

WHEN THERE'S A NEED FOR SPEED

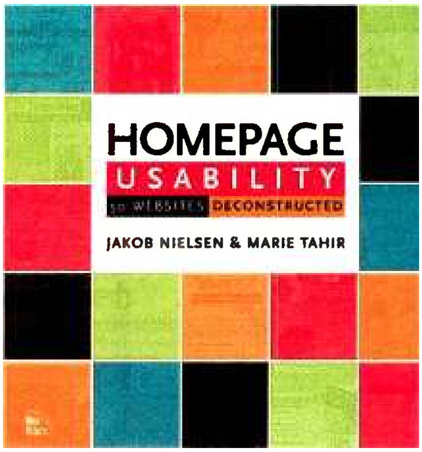
Speed has played a key role in computer use since the inception of the digital age in the 1940s. The very raison d'être of electronic machines is their ability to perform computations and process information much faster than humans can. The issue of speed is complex: Sometimes it is not always what it's cracked up to be, and other times it is given short shrift. Understanding the differences can help you make smart PC buying decisions, as well as smart Web site design decisions.

The central processing units (CPUs) of today's run-of-the-mill personal computers have come a long way in terms of speed. They are much faster than those of the multi-million dollar mainframe computers were—the ones that were leading us into the future in the 60s and 70s. PCs today are ten times more powerful than they were just five years ago

This mind-boggling increase in processing speed was predicted and codified in 1965 by Gordon Moore, who would become the co-founder of Intel, when he said that the number of transistors per square inch on integrated circuits had been doubling and would continue to double every year. Though this doubling would later slow from every year to 18 months, the increase in capacity has continued; and it's emblematic of the personal computer revolution. It's an increase that's unprecedented in other spheres of human endeavor.

FASTER ISN'T ALWAYS BETTER

To those involved with personal computers, this is heady stuff; and it has led to an infatuation, even an obsession, with speed. It taps into the Western notion of progress, of ever-increasing efficiency, output, and standards of living. However, the infatuation is misguided. "Speed is an artificial need," says Rob Enderle, an analyst for the Giga Information Group, a market research firm in Santa Clara, CA. "It's analogous to cars with big engines. Bigger is not always better. Neither is faster."



"On the Web," says Jakob Nielsen, author of the new book Homepage Usability: 50 Websites Deconstructed, *"you have design Darwinism—survival of the easiest." The theme here is technology for people, not for technology.*

There's a countervailing notion here, more Eastern in nature, of appropriate technology. In practical terms, very few people today need the fastest PCs—those that run the Intel Pentium 4 2.0-GHz CPUs, which have recently reached the market, or the equivalent chips from AMD or Motorola. For common tasks such as word processing, spreadsheets, business graphics, Web surfing, and e-mail, slower and less expensive CPUs are more than adequate. On the other hand, if you're engaged in CPU-intensive tasks such as high-end image editing, video editing, digitizing music, or computer-aided design, the higher end CPUs can be cost effective.

There are other factors besides cost effectiveness that can affect a buying decision. A high even number such as 2.0 GHz or 2 billion cycles per second is psychologically compelling in the same way as a .400 batting average or a Dow of 10,000 is. Still, on the whole, the importance of CPU speed is overrated, the single-most overrated aspect of personal computing today

What is undoubtedly underrated is the time it takes Web pages to load. Sure, it's widely known that a high-speed cable or DSL modem can dramatically improve the quality of your surfing experience. In fact, the biggest Internet traffic jam for the past several years hasn't been CPU speed, but modem speed—a bottleneck that won't disappear until high-speed Internet access becomes universally available.

WEB USERS WANT IT—NOW

What's not commonly known is that even with high-speed access, slow-loading Web pages can still be a problem. The Web won't be truly efficient until browsing from one page to the next is as speedy as browsing pages in a newspaper or magazine. A recent study by market research firm, Jupiter Media Metrix, underscores the importance of fast-loading Web pages. The study found that 40 percent of Internet users will visit a site more often if its pages load faster; while only 20 percent are interested in multimedia or rich media features, which load much slower than text and simple graphics

Some Web page designers look at flashy technologies such as Shockwave as a way to make their sites look hip and cutting edge. Yet many Web page visitors look at these technologies as cloying eye candy that just slows them down. People surfing the Web generally have short attention spans. This is the era of VCRs and microwave ovens, an age of immediate gratification. If you force users to cool their heels at your Web site, satisfaction elsewhere is just a click away.

That's why the best Web sites are simple and are more likely to be around in the future. "On the Web," says Jakob Nielsen, author of the new book *Homepage Usability: 50 Websites Deconstructed*, "you have design Darwinism—survival of the easiest." The theme here is technology for people, not for technology.

Web services are another offshoot of the Internet era, about to be born into the public domain. The destiny of the World Wide Web lies in efficiency, user-friendliness, and technological sophistication; and Web services are promising all of this and more.

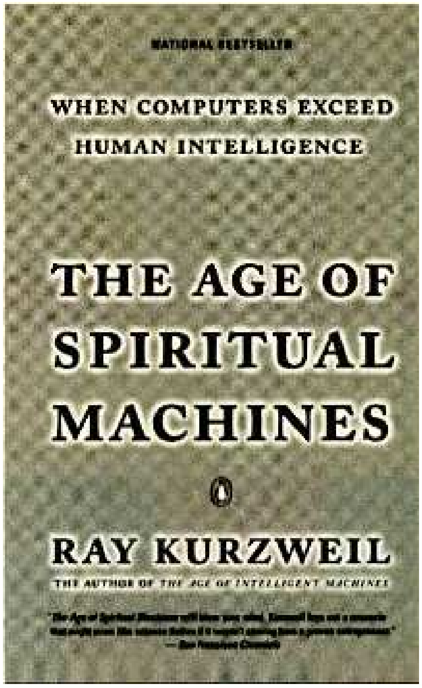
THE FUTURE OF DIGITAL TECHNOLOGY

"If you can look into the seeds of time, and say which grain will grow and which will not, speak then unto me." Shakespeare's words are just as wise today, but this hasn't stopped people from trying to divine the future.

The latest future-oriented computing issue goes by the over-broad moniker "Web services." The companies behind them, including Microsoft with its Microsoft .NET initiative, and Sun with its Sun ONE initiative, would have you believe that your computing future lies in their hands.

A Web service is a remote server, one you can connect to through the Internet, that promises access to any program. It doesn't matter where you are or what type of computer you're using. Experts predict that it will be two or three years before Web services have any chance of replacing your word processor and other desktop applications. I predict that if they try to dominate your computing experience, they'll fail. The personal-computing revolution is about gaining control through customizing and personalizing, not losing it.

Still, the prospect of computing



In his book, The Age of Spiritual Machines, *Ray Kurzweil states that by the year 2030, common $1000 personal computers will grow so greatly in speed and capability that they will achieve the full capacity of the human brain.*

without losing any functionality is compelling. Other work is under way to create ever-faster computers through new chip technology. The engines of tomorrow's PCs may be based not on silicon dioxide but exotic new compounds such as perovskite oxide or even the stuff of life itself, DNA. Faster computers may finally make speech recognition as workable as typing and may lead to computers like HAL from the movie *2001: A Space Odyssey*

The future will be truly mind-boggling, according to the prognosticators. In his book, *The Age of Spiritual Machines*, Ray Kurzweil believes that by the year 2030, common $1000 personal computers will grow so greatly in speed and capability that they will achieve the full capacity of the human brain. Kurzweil, a prominent inventor and business leader in the field of artificial intelligence, makes other imagination-sparking predictions: By the end of this century, we'll achieve virtual immortality by being able to download our minds, memories, and consciousness into robots. Ultimately, he reasons, human and machine intelligence will merge and become indistinguishable, growing exponentially until it will be able to control how the very universe evolves.

FORECAST FLOPS

It's easy to scoff at such notions as the stuff of science fiction. Yet the past is littered with examples of the shortsightedness of others, including those deeply involved with technology. Here are some of the more notable examples of failures of the imagination:

- "640K ought to be enough for anybody." Microsoft founder and Chairman Bill Gates, 1981, about computer memory
- "Computers in the future may weigh no more than 1.5 tons." *Popular Mechanics* magazine, 1949
- "I think there is a world market for maybe five computers." Thomas Watson, president and CEO of IBM, 1943
- "But what ... is it good for?" Engineer at IBM, 1968, commenting on the microchip
- "There is no reason anyone would want a computer in their home." Ken Olson, founder and chairman of Digital Equipment Corp., 1977
- "This 'telephone' has too many shortcomings to be seriously considered as a means of communication. The device is inherently of no value to us." Western Union internal memo, 1876
- "The wireless music box has no imaginable commercial value. Who would pay for a message sent to nobody in particular?" David Sarnoff's associates in response to his pushing for investment in radio in the 1920s. (Sarnoff founded NBC, the first radio network, and later introduced TV broadcasting to the U.S.)
- "Who the hell wants to hear actors talk?" H.M. Warner, co-founder and president of Warner Brothers, 1927
- "We don't like their sound, and guitar music is on the way out." Decca Recording Co. rejecting the Beatles, 1962.

On the other hand, you don't want to bet the ranch on anyone's psychic vision. In a book I wrote called *Straight*

(Continued on page 54)

TED NEEDLEMAN

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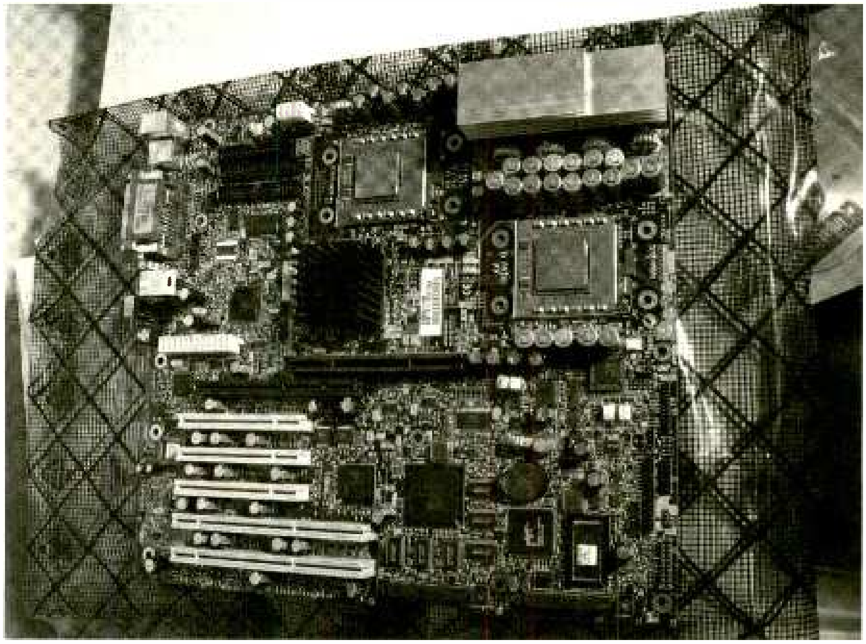
YOUR OWN MONSTER WORKSTATION, PART 1

With a title like "Peak Computing," this column has, and will continue to, run the gamut. Sometimes Peak Computing means adding newer, higher performance components and peripherals. Other times, it consists of fine tuning or trouble-shooting the system that you already have.

In this and the following month's columns, we'll take a look at truly Peak Computing, a state-of-the-art workstation that you can build yourself. It's a bit more expensive than the other PCs we've put together recently; but, for certain types of applications, our "Monster Workstation" is in a class by itself and the equal of commercial products costing almost twice the price.



We went with the Tyan Thunder i860. This is a terrific motherboard based around Intel's i860 core logic chipset. The Thunder i860 has an on-board LAN controller, integrated audio using the Analog Devices AD1885 chipset, an integrated SCSI controller with Ultra 160 support, and support for up to 4 GB of RDRAM.

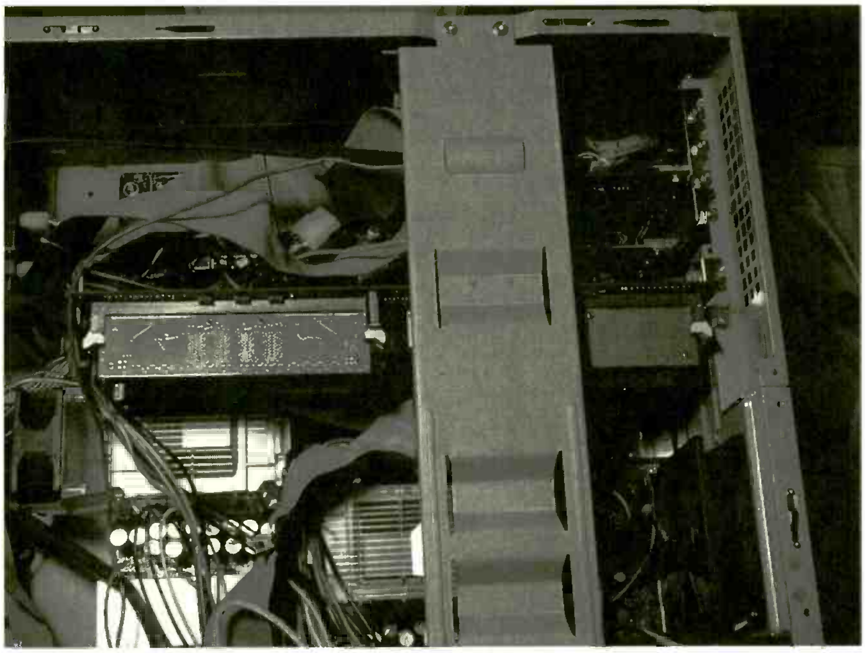
WHAT'S A WORKSTATION, ANYWAY?

Before we talk about what went into our Monster Workstation, let's take a minute to discuss what differentiates a workstation from a standard PC. In many respects, there's not much, if any, difference. A workstation is usually just a PC that's been configured to offer better performance for a specific type of application. Most of the time, workstation applications are graphics-oriented. These applications include CAD (computer-aided design), modeling, animation, graphics design (i.e., drawing, painting, and image editing), and digital video editing and production.

What makes a workstation different is that its components and peripherals have been optimized for these types of applications. For example, a CAD or modeling workstation will often have an oversize monitor (21 inches or so) and a graphics card that's optimized for 2-D graphics rendering. These graphics cards, from vendors such as ELSA and 3DLabs, often have abysmal frame rates when compared to general-use video cards, but excel in tasks such as shading and mapping textures.

Input and output is another area where workstations differ from more run-of-the-mill PCs. Image and CAD files are often huge, and having fast disk drives with high bandwidth data transfer really speeds up the overall performance of a workstation. This is also true of the workstation's RAM memory. Most workstation applications are both memory-intensive, working better when lots of RAM is available, and fast running with high-speed, high-bandwidth memory.

Finally, there's the processor. Some workstations use custom processors, often RISC (reduced instruction set CPU) oriented. This type of CPU provides fewer hard-wired instructions, but performs the instructions that it does provide very fast. Intel Corporation takes a somewhat different tack with



We were able to obtain a terrific case from Ever Case Technologies. This vendor's ECS5000LX case is specifically designed to accommodate the Tyan Thunder i860 motherboard.

its workstation processors. Based on the latest Pentium 4 core architecture, the new Xeon processors have hyper-pipelining (can execute multiple instruction streams simultaneously); expanded SSE2 instruction sets designed to improve performance on video, graphics, and audio-related operations; and the design works in a symmetric multiprocessor environment, with more than a single CPU residing on the workstation.

PICKING BRAINS

Our Monster Workstation is built around a pair of these new Intel Xeon CPUs, each running at a clock speed of 2 GHz. These processors are optimized for workstation use and cost a bit more than the standard Pentium 4 of the same clock speed. We'll have a complete price list in the next column. AMD also has a CPU designed for multiprocessor use, the Athlon MP. This CPU is less expensive than the Intel Xeon. However, the Athlon MP is not optimized for workstation applications and is more appropriate for less serious applications like gaming.

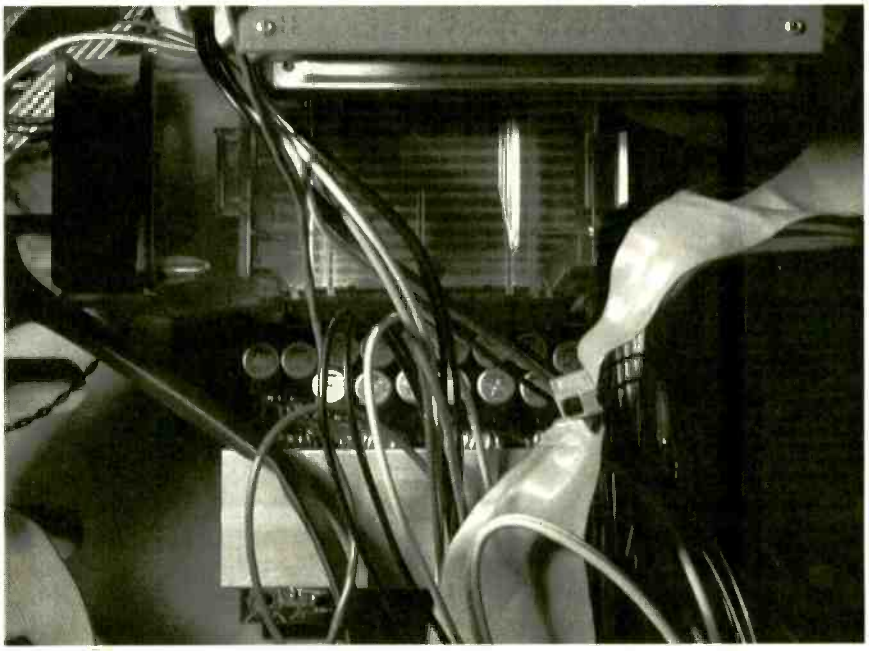
Originally, we designed the workstation for use as a DVD transcoding system. With new DVD burners, it's easy to create your own DVDs that will play in most PC's DVD-ROM drives or in stand-alone DVD players. Transcoding is the process of taking video in AVI and other formats and converting it into the MPEG-2 format used in DVDs. This is a tremendously computing-intensive operation.

Our Monster Workstation is also terrific for performing applications that can take advantage of its dual CPU configuration. The application has to be specifically engineered to do this, and many still aren't. Fortunately, most of the high-end graphics and CAD applications from Adobe Systems and AutoDESK will use a second CPU if present.

A NURTURING MOTHER(BOARD)

To take advantage of the Xeon processor's capability of running in a multiprocessor environment, you need a motherboard that's been designed for this application from the start. The three major motherboard vendors producing motherboards for multiprocessor Xeon workstations are iWill, Tyan, and SuperMicro. We went with the Tyan Thunder i860. This is a terrific motherboard based around Intel's i860 core logic chipset. The Thunder i860 has an on-board LAN controller, integrated audio using the Analog Devices AD1885 chipset, an integrated SCSI controller with Ultra 160 support, and support for up to 4 GB of RDRAM. The RAM is mounted on an external memory card. Kingston Technologies very generously supplied us with 1 GB of RDRAM in the form of four 256-MB RIMMs. For memory bandwidth optimization, the motherboard design allows these RIMMs to be accessed through four channels, two for each of the processors. This set-up allows the memory to run at full speed and enables high-bandwidth data-transfer capability.

In addition to supporting SCSI devices, the Thunder i860 also pro-



The case has plenty of drive bays, space for several additional case fans, and a support bracket for the RAM card. It features a hefty 430-watt power supply from Enhance Electronics that is also specifically designed for dual Xeon-based motherboards.

vides a standard ATA/100 IDE controller. We used this ATA/100 controller for the two DVD recorders we mounted in the Monster Workstation. The hard-disk drives we used were a pair of new DiamondMAX D740X models. These each have a capacity of 80GB of storage space and spin at a fast 7200 RPM, which reduces latency (the amount of time that is spent waiting for the desired sector to come under the read/write head). More importantly for our use, the DiamondMAX D740X features a new ATA/133 interface, which speeds up the data transfer between the drive and motherboard bus. Maxtor supplies these drives with a new ATA/133 IDE controller from Promise Technologies.

The Tyan Thunder i860 motherboard offers an AGP slot that will accommodate a standard 4X AGP video card or an AGP Pro card. We used a Leadtek WinFast GeForce3 Ti200 TDH board in the "Monster." More of a general-purpose card than one meant for CAD or modeling, this card so far has met our needs. The Thunder i860 also has both standard PCI slots and the 64-bit version used in most workstations. There are three 32-bit PCI slots and a pair of the 64-bit slots. We actually used one of the 64 bits to upgrade the LAN capabilities, dropping in an Intel Gigabit Ethernet adapter to speed up file transfers to our network server.

BOXING IT UP

The Tyan Thunder i860 motherboard does, however, limit you as far as a case and power supply. There are a fair number of cases on the market that can accommodate the Extended ATX form factor of the motherboard (13 × 12 inches). Power is another thing entirely. The multiple processors require more power and a slightly different configuration than the typical Pentium 4 supply is designed for. Fortunately, we were able to obtain a terrific case from Ever Case Technologies. This vendor's ECS5000LX case is specifically designed to accommodate the Tyan Thunder i860 motherboard. It features a hefty 430-watt power supply from Enhance Electronics that is also specifically designed for dual Xeon-based motherboards. The case has plenty of drive bays, space for several additional case fans, and a support bracket for the RAM card.

Since our primary use of the Monster Workstation was DVD transcoding, we added two DVD burners. The Pioneer A03 can burn DVD-Rs, one-time use discs with a 4.7-GB capacity. It can also use the more expensive DVD-RW discs. The new Hewlett Packard dvd100i drive uses only rewriteable DVD-RW+ discs, a different format from that used on the Pioneer A03. Both drive vendors promise compatibility with stand-alone DVD players. Verbatim makes media in all of these "flavors" and was very generous in providing plenty of discs to perform our testing.

PARTING WORDS

Topping off any workstation is the operating system. Various versions of Linux offer good multiprocessor support. In the end, however, we went more mainstream, choosing Microsoft XP Professional so that we could use the standard and popular applications such as *Photoshop* and *Premiere*. Keep in mind if you want to build your own multiprocessor system that only Windows 2000 and XP Professional support more than a single CPU. Other versions of Windows don't.

Next time, we'll take a look at how this all goes together and how it performs. ■

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WILLIAM SHEETS, K2MQJ, and RUDOLF F. GRAF, KA2CWL

Basic Regulator Circuits

This article will discuss a very basic subject—simple power-supply regulators. Most experimenters will use off-the-shelf power-supply regulators available as IC functional block devices. Actually, for most experimenters, the regulator can usually just be a 7800- or 7900-series IC. You will seldom build regulator circuits, unless your project is a large, high-energy power supply or a very high-powered audio amplifier. Even then, power supplies and high-power amplifiers are often better and more cost effective if purchased ready-made. Many companies provide such items at a reasonable cost, often less than the cost of the large transformers, filter capacitors, and heatsinks. You will also need to obtain PC boards, small parts, meters, and a case. Power supplies are basic, off-the-shelf items.

How "The Wheel" Works

So why discuss regulator circuits? Why reinvent the wheel when someone has already done it, cheaper and better than you can probably do? For openers, it is always important to know how and why "the wheel" works. Eventually today's wheelmakers and wheel engineers will stop designing, improving, and making wheels. If no other wheelmakers and designers replace them, eventually there will be no more wheels. Technology can be lost and forgotten. That is why it is important to know how wheels work or anything else for that matter.

If you do not understand it or have never done it, "old" technology is new to you and something worth exploring. In addition, you just might have fun and learn something new by reading articles like this. Also, you won't become just another technical whiz who cannot solder, use an oscilloscope, and whose electronics knowledge is limited to trendy pseudo-science, the latest in stereos, and what's hot at the computer store or software emporium.

This point made, let's discuss simple, plain-jane power-supply regulator circuits. You will also better understand the black-box ICs you will use in your projects and their various applications. The subject of power-supply circuits is complex and cannot really be adequately covered in a short article. However, by understanding a few basic circuits, you can figure out how some of the more sophisticated supplies operate. Packaged IC regulators such as the 7800/7900 series and the LM723 use these basic circuit ideas in their internal circuitry, in various forms and guises.

More Power To You

A power supply uses a regulator to maintain output voltage or current at specified limits. An ideal power supply would have zero internal resistance (ideal voltage source) or infinite internal resistance (ideal current source) so that the output voltage or current is independent of load. These sources would have to be capable of supplying infinite amounts of power and, of course, exist only in theory. They are used in engineering for analytical purposes.

A real-world supply will have finite internal impedance. This impedance may vary with the load on the supply. The maximum current a voltage source can deliver into a short circuit or the maximum voltage a current source can deliver across a load can sometimes be quite high. For example, a common 12-volt automobile battery can deliver as much as 1000 amps or more into a dead short (and possibly explode in the process).

Constant-current sources are less common. One common application was the use of a constant-current transformer to drive a series street-lighting circuit (used in the past for arc and incandescent lighting applications). These circuits could deliver several kilovolts or more if the circuit were to be opened. The lamps had devices in the circuit such that the normal 120 or 240 volts across the lamp would not have any effect, but the opening of a filament would cause the high voltage to appear across that lamp. The device would effectively short-circuit the lamp, maintaining circuit continuity.

This principle is used in today's Christmas decorations, where 25–50 series-connected low-voltage bulbs have built-in shunts that will conduct when full-line voltage appears across the open bulb, maintaining continuity of the circuit. Both constant-voltage and constant-current supplies can be approximated electronically with a regulator circuit to almost any degree desired, within the current and voltage restrictions imposed at their inputs. Often, both forms of regulation are provided. For example, in a current-limited power supply, the supply provides a specified maximum load current with the output voltage dropping off at heavier loading. The output voltage can exceed the input voltage in the case of switching-type regulators and electromechanical regulators (transformers with motor driven tap switching, etc.), but the linear regulators to be discussed produce an output voltage that is lower than the input voltage.

Therefore, some power will be dissipated as heat. Switching regulators make use of energy-storage components (L and C) and generally have better efficiency than linear regulators, often 65–90 percent or better. In addition, the elimination of heavy, expensive, large 60-Hz transformers will reduce cost size and weight. Eliminating the transformer results in greater circuit complexity and greater circuit noise due to switching transients. This factor often limits the use of switching regulators in applications where noise may cause problems (i.e. low-

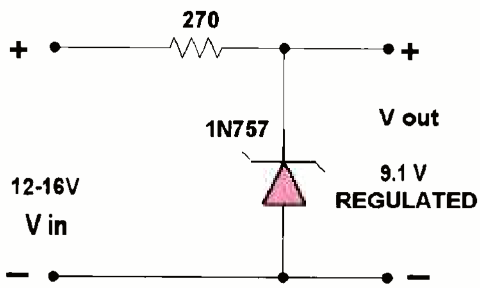

Fig. 1. This schematic is a basic shunt-regulator circuit. A zener diode is placed in parallel with a resistor in order to regulate the 12–16 volt input to a 9.1-volt output.

level audio and RF circuits operating at frequencies in the noise spectrum of the power supply).

Keep The Noise Down!

Remember that 60-Hz rectifiers operating into large-capacitor input filters can produce large AC-line current spikes and RF noise, especially if fast rectifier diodes are used. This 60-Hz noise can be as bad as a poorly designed switching supply might produce, making 60 Hz noise well up into the HF radio spectrum. So 60-Hz supplies are not necessarily always as noise-free as you may think. Linear regulators will usually yield lower noise, ripple, and better regulation when a really pure DC supply is needed. Regulator-circuit complexity is reduced greatly by the many available regulator IC devices, and a relatively complex regulator of high performance is easily placed in an IC chip. IC regulators supplying fixed voltages of 3–24 volts at currents from 100 mA up to several amps are readily available and cheap, and they can easily be interfaced to higher-power bipolar or FET devices for high-current supplies.

These regulators are commonly three-terminal devices (input, common ground, and output) and often only require a few external peripheral components (the common 7800- and 7900-series regulators only need two capacitors of 0.01 to 1 mF, and only under certain conditions.) These regulators will easily provide well under 1-percent regulation and offer some current-limiting and built-in fault protection. Switching regulators and voltage converter ICs that use a few peripheral capacitors and little else are also available. These low-cost regulators and converters make it practical and easy to supply individual circuits with special voltages not supplied by a systems main-power source, such as higher or opposite polarity voltages. This setup may often circumvent power supply limitations, allowing more design freedom.

The simplest regulator makes use of a two-terminal device that has the property of maintaining a constant voltage across it (zener diode, gas-discharge tube) or a constant current through it (field effect transistor, temperature-limited vacuum diode). The basic circuit is shown in Fig. 1. A zener diode is generally used, although gas-discharge devices (common in vacuum-tube circuitry, but relatively rare nowadays) are sometimes used for higher voltages. For still higher voltages, these devices can be connected in series in any combination. A current-limiting (ballast) resistor must be used; as these devices will attempt to maintain constant terminal voltage, drawing whatever current is needed from the supply to do so.

Efficiency Is Key

The impedance of the regulating device can be very low, and it can easily draw destructive amounts of current without a limiting resistor. This circuit (Fig. 1) is a shunt-type regulator, as the regulating device is shunted across the load. Often, for low-power applications where only a few milliamperes of current are required and regulation (percentage change of voltage or current under differing loads) of a few percent is adequate, this approach will work very well. The efficiency is generally poor, especially at light loads, since the total current through the ballast resistor is the sum of the load current and the regulator current needed to maintain the voltage. When the load is removed or varies, the excess current must flow

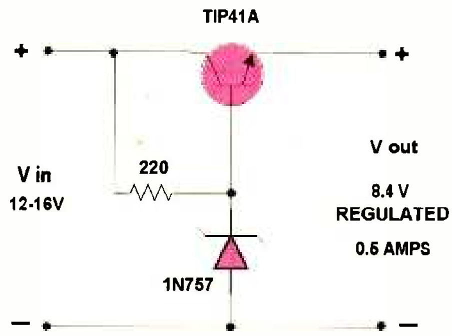

FIG 2a
SIMPLE REGULATOR

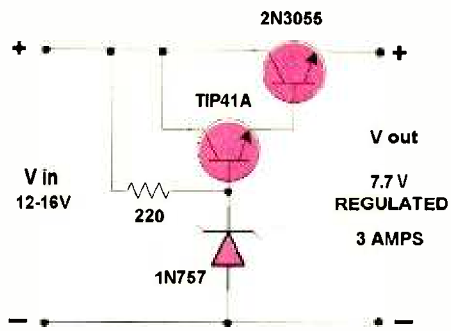

FIG 2b
SIMPLE REGULATOR
FOR HIGHER CURRENT

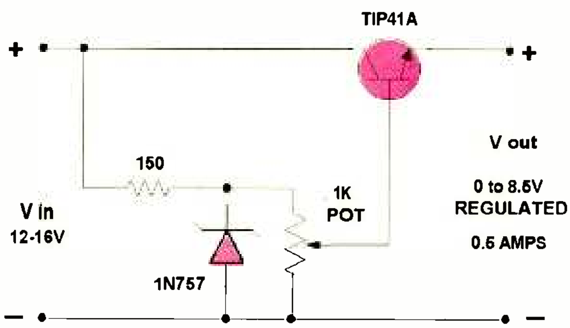

FIG 2c
SIMPLE ADJUSTABLE REGULATOR

Fig. 2. Here are three regulator circuits that incorporate transistors. All of the circuits can handle an input of 12–16 volts. Each successive circuit grows slightly more complex.

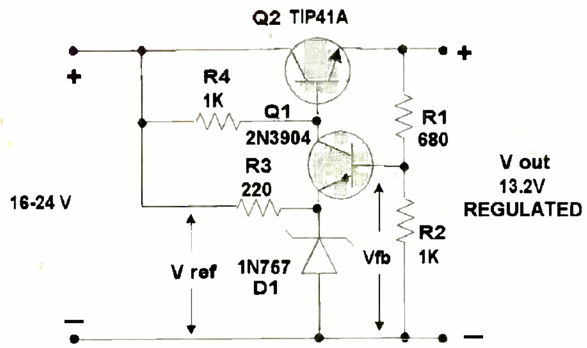

Fig. 3. This is an example of a simple feedback regulator that uses a single transistor-error amplifier. Resistors R1 and R2 perform as a voltage divider that is used to sample the output voltage.

through the regulator. While not a problem in a circuit such as a receiver-local oscillator drawing only a few milliamperes, it would be a problem in a circuit such as a small digital system drawing 1 amp at 5 volts.

In certain cases (LED displays, on-off controls), the system may draw less than 50 milliamps in standby and 1 amp while active. A zener-diode regulator would be very inefficient, since around 1 amp would have to flow through the zener when the system was inactive and not drawing its operating current. If the input voltage was 12 volts, the efficiency of the 12V to 5V regulator would be very poor with over 1 amp constant load on the 12-volt supply, even when the 5-volt load was light. This would be 12 watts or more of useless heat generation, a very inefficient situation. A solution is to use an active regulator that does not require so much current to operate.

However, note that there will always be some voltage drop across the regulator. The regulator circuit is an amplifier and will therefore need some voltage to operate. The base-emitter voltage of the pass transistor has a value of 0.6 to 0.7 volts, and there will be some voltage drop in the bias resistors. The input voltage must always have a minimum value, generally 2 to 5 volts, above the maximum expected output voltage; and it must never fall below this voltage or regulation will be lost. This minimum voltage must be maintained at maximum load, under minimum-input line-voltage conditions. Instantaneous variations due to input-supply ripple, load transients, etc. below this level will cause loss of regulation ("drop-out").

In Fig. 2A, a transistor connected as an emitter follower is used to reduce the current drawn by the regulator device. The zener diode has 10 or 20 mA flowing into it. This voltage is fed to the base of the transistor, called the "pass" transistor, as it is used to pass the load current. It can be a large power transistor capable of handling several amps of current. The load current consists of the collector current, which is the lion's share of the current, plus the base current. The base current is equal to the collector current divided by the DC gain (or β, typically = 50) of the transistor. With a β of 50 and a load current of 1 amp, the collector current would be β/(β+1) of 1 amp or 50/51 amps and the base current would be 1/(β+1) or 1/51 of an amp. This is a little less than 20 mA. The current flow is shown in Fig 2A.

Figure 2B shows how an intermediate transistor can act as an intermediate stage in case the pass transistor is a very high-current unit. Note that with no load, the only current drawn by the circuit is that of the zener diode. Also note that by placing a pot across the zener diode and connecting the wiper to the base of the transistor, a variable output voltage may be obtained (see Fig. 2c).

The problem with this circuit is that it is not any better (actually, slightly worse) a regulator than the zener diode. There is no mechanism to guarantee the output voltage to the load. In addition, a small drop in output voltage occurs due to the base-emitter drop in the pass transistor (0.6 to 0.7 volts per transistor typically). There is additional resistance drop in the potentiometer if used for varying the output voltage. This resistance causes some loss in regulation. The regulator cannot "know" if there is a drop in the output voltage. What is

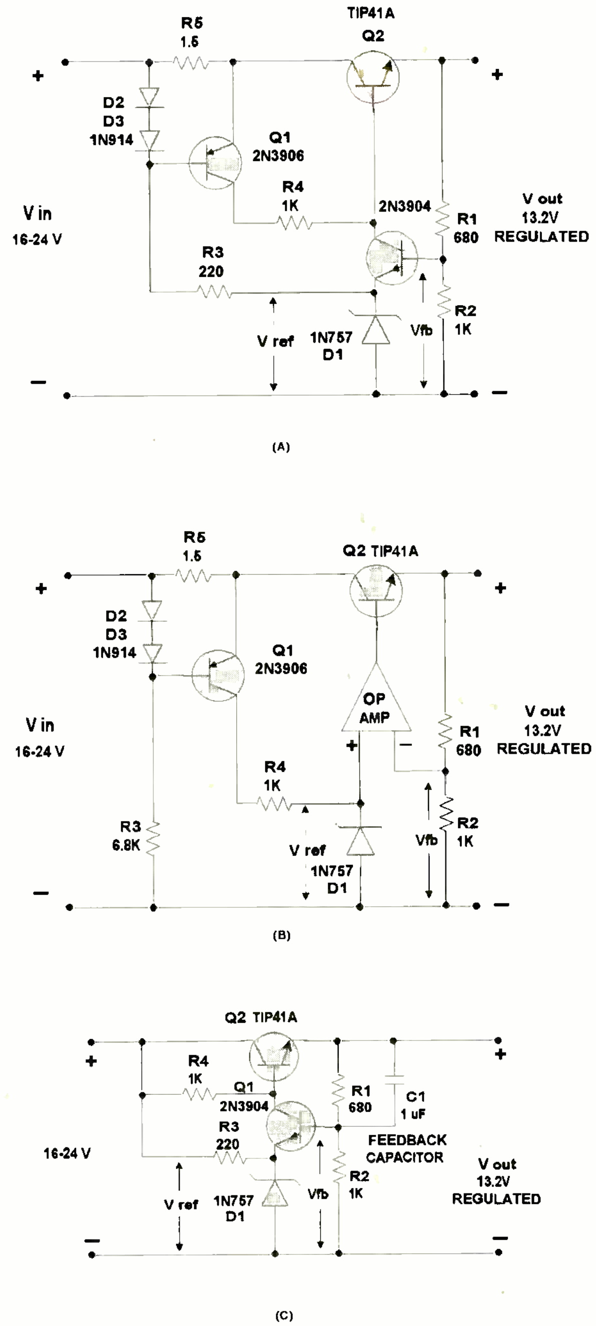

Fig. 4. These are three regulator circuits that each employ a unique method of tweaking the output—current-limiting transistor networks, improved regulation through the use of an op-amp, and improved transient regulation using a capacitor.

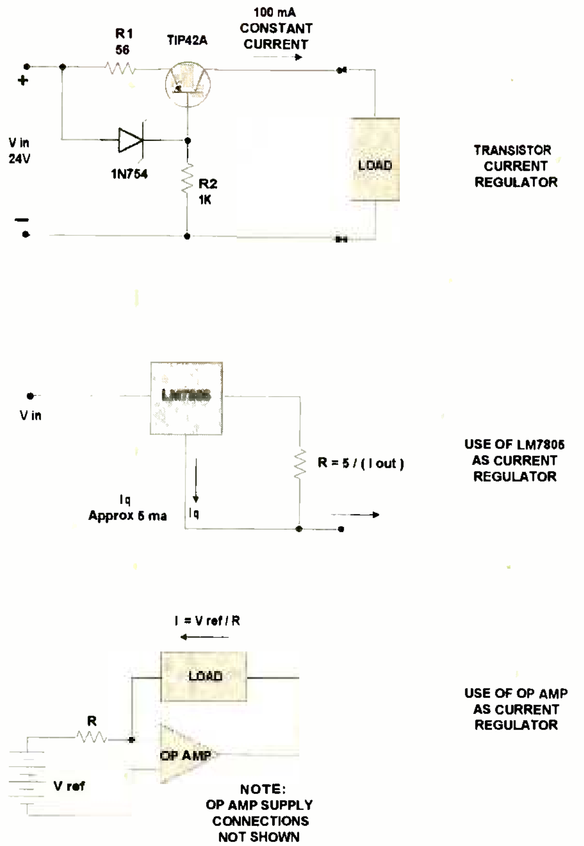

Fig. 5. The circuits above are examples of constant-current regulators. One circuit uses an LM7805 to regulate the output power, while the other circuit uses an op-amp for the same purpose.

really needed is some way of sensing the output voltage, comparing it with a fixed reference, and automatically adjusting the output voltage to the desired value. This requirement implies a feedback or servo system that will act to control the output voltage. We will show you a very basic way to do this with a few additional parts.

A very basic feedback regulator in which the output voltage has some say in its exact level is shown in Fig. 3. A voltage divider, R1 and R2, samples the output voltage and feeds it to the base of transistor Q1. The emitter of Q1 is held at a fixed and regulated (we hope) voltage produced by the drop across zener diode D1. This drop is produced by bias current from R3 and the emitter current of Q1. Should the output voltage drop, Q1 will be turned off, drawing less current through bias resistor R4. The collector voltage will rise, increasing the voltage at the base of pass transistor Q2 and, therefore, the emitter of Q2, which happens to be the output terminal for the power supply regulator. This rise in voltage will be passed to the base of Q1, compensating for the initial drop. The overall effect will be the stabilization of the output voltage.

No Such Thing As Perfect

However, this compensation is not perfect. The regulator circuit is a feedback amplifier with finite gain. Since the voltage gain comes mainly from Q1, the circuit may have a net open-loop voltage gain of 20–100 or so—depending on the gain of Q1, the power-supply load, the impedance of the zener diode, and other factors. Loop gain would be defined as the product of the total gain multiplied by the feedback factor. The feedback factor in this case is the ratio R2/(R1+R2). The higher the loop gain, the better the regulation, all else being equal. In practice, this circuit will produce an improvement in regulation of around 10X or better over that of the previous circuits. There are limitations with this circuit, some of which are:

- Output voltage cannot be less than the zener voltage plus the base-emitter drop in Q1
- No means of current limiting or short-circuit protection exist
- Maximum regulated output voltage is limited, as there will always be a voltage drop across R4
- Regulation is progressively poorer as output voltage increases, since feedback factor R2/(R1+R2) decreases
- Since some of the bias currents (through R3 and R4) come from the unregulated side, output will be influenced by input voltage variations, degrading regulation

These problems can be solved with circuit changes and additional components. A solution to the first one is to use a low zener voltage, although the most stable zeners are around 5 to 8 volts. It is possible to use a separate floating power-supply circuit to provide voltages below (negative) the ground level and return R2 to a negative voltage instead of ground. Place a resistance in series with the input; and the voltage drop across this, a function of load current, can control the regulator output. Additional transistors or an op-amp can be used to get more open-loop gain

Some Solutions

Figure 4A shows one method by which current limiting can be added. Resistor R4 is in series with a PNP transistor, Q3, acting as a current source. This resistor is necessary to limit the current supplied to D1. Diodes D2 and D3 produce a fairly constant voltage that is 1.4 volts below the regulator input voltage, at the base of Q3. As long as the voltage drop produced across sampling resistor R5 by the pass-transistor collector current is less than about 0.7 volts, Q3 conducts. As the load current increases, the drop across R5 will increase to the point where it starts cutting off Q3. Now, R4 can pull down the base of pass transistor Q2, causing the regulator output voltage to drop off. Since this current also biases reference zener diode D1, the reference voltage also drops—reducing the output voltage. In this way, the current drawn from the regulator can be limited. About 0.7 volts drop across R5 will start current limiting, so R5 should have the value of 0.7/(Current Limit), about 0.7 ohms for 1 amp, 0.35 ohm for 2 amps, etc.

Looking at Figure 4B, we see how an op-amp can be added to improve regulation. Note that the gain will now be very high. However, frequency compensation will probably prove necessary in some cases, as loop phaseshift may be such as to cause oscillation at some or all load conditions. The bias for the op-amp may be obtained from the regulator itself, although generally a separate auxiliary low-power supply is preferable. The op-amp may need a negative source, especially if the regulator is expected to be variable or to go down to

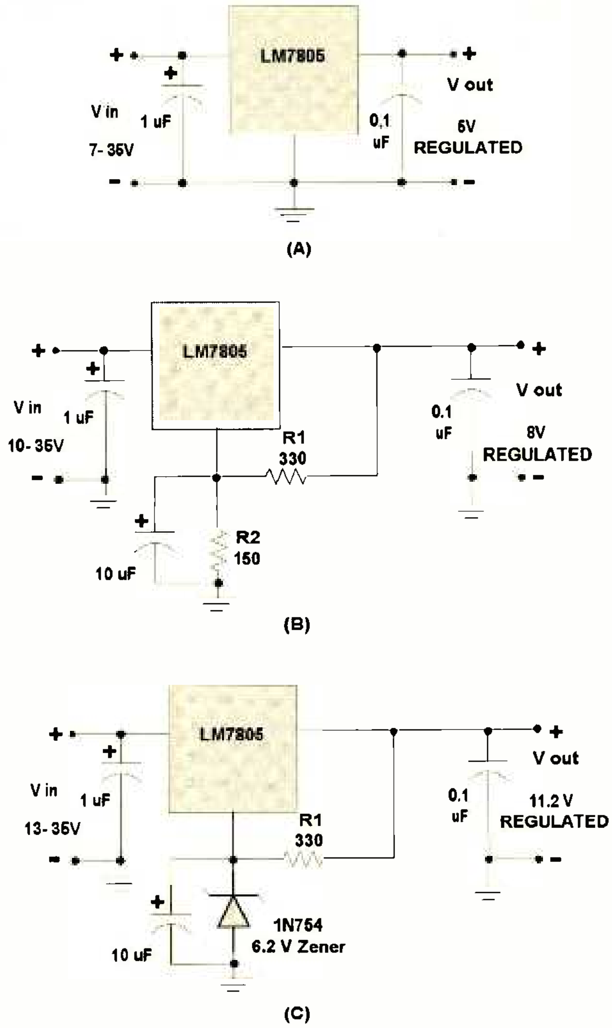

Fig. 6. All three of the circuits above contain the LM7805 voltage regulator. The LM7805 is widely used, affordable, and practical. As you can see, a variety of voltages can be used with the popular regulator series.

zero volts output, as in a laboratory power supply.

A way to improve transient regulation of the regulator in Fig. 4 is shown in Fig. 4C. The capacitor provides increased feedback for AC signals. Note that this may cause problems with loop stability in some applications using op-amps.

Capacitors can and often are placed across the regulator output terminals to reduce residual ripple and to ensure low output impedance, but be aware that capacitive loads may cause problems with loop stability. Also, if the input voltage falls below the output voltage due to a short or component failure or sudden removal of the input voltage, this capacitor can discharge back into the regulator, possibly damaging the pass transistor emitter-base junction due to reverse over-voltage. A protection diode is often added across the pass transistor to guard against this type of fault.

Referring to Fig. 5, we see a few simple constant-current regulators. The collector current of a transistor can be held constant by the use of a zener diode and emitter resistor, as shown in Fig. 5A. The emitter current equals the zener voltage less the base emitter drop (about 0.6 to 0.7 volts) divided by the emitter resistor. The current will remain constant within a percent or two as long as the load voltage stays below the input voltage minus the zener (or other reference) voltage plus the saturation voltage of the transistor. The maximum output voltage under specified current conditions is sometimes called the compliance. This principle is widely used inside ICs where a high impedance current source is needed.

Figure 5B shows the use of a 5-volt regulator IC to produce a constant-current source. The three-terminal regulator maintains 5 volts across the current-sensing resistor. A small current flows out of the common lead, but this is typically only 5 mA and is fairly constant. A power transistor can be used to handle higher currents, if needed. With the 7805 regulators and adequate heatsinking, a constant current source up to about 1 amp can be obtained.

Using an op-amp, you can produce a constant current (see Fig. 5C). Since the sum of currents at the summing junction of an ideal op-amp must be zero, the op-amp will deliver to the load whatever voltage is needed to force a current through the load equal to the reference current. The reference current is equal to V_{in}/R1.

One application of this principle uses a high-voltage capability op-amp to check breakdown voltages of semiconductor junctions. The desired current is fed to the op-amp input, and a voltmeter connected to the op-amp will read the voltage needed to force this same current through the semiconductor junction. Since this current can be constant, it makes safe, nondestructive testing possible.

Since ICs can have many transistors and resistors built in, additional regulator features are easily added. Numerous manufacturers publish data sheets for their IC devices that show some or all of the internal circuitry. It is often necessary to provide this information for applications and interfacing not shown in their data sheets or discussed in their application notes. You might want to get some of these data sheets and examine the internal circuitry of a few of these chips. You will be better able to use them in original designs and not be limited to "cookbook" published circuits that are not exactly what you want. Yes, you really do have to know what is going on in the black box if you ever are expecting to do anything original. Working blind may get you into problems and hours of futile effort that can often be avoided if you know what is happening.

Ample And Affordable Supplies

A lot can be done with inexpensive three-terminal regulators. Figures 6A, 6B, and 6C contain a few circuits that use the

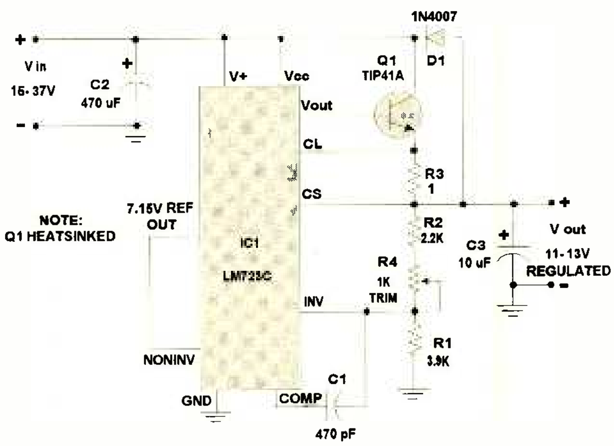

Fig. 7. The LM723 IC is another favorite for building power supplies. Using resistors, the output voltage can be programmed to fit your needs. The chip has an internal reference of 7.15 volts, nominally.

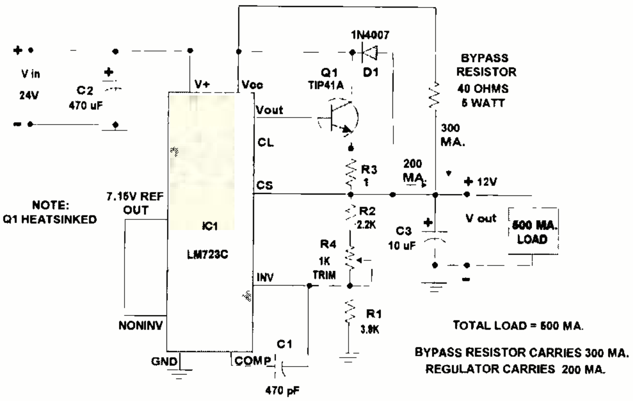

Fig. 8. A resistor is placed across the regulator in the circuit above in order to lessen the dissipation and heat load that the linear regulator experiences during performance.

7805. These widely-used regulator IC chips are probably the easiest for the experimenter to obtain. They come in versions from 100-mA TO-92 and surface-mount types to large TO-3 types good for several amps. While all these are made in various output voltages from 3 to 24 volts, it is possible to get output voltages higher than their rated output without much sacrifice in performance. For example, you need 8 volts from a 5-volt regulator. While an 8-volt regulator is available (LM7808), your local electronics supplier may not stock them, your other suppliers have a minimum order, or you may have plenty of 5-volt units and not want to buy 8-volt units for just one application. You can fool the LM7805 into delivering 8 volts, using the circuit in Fig 6A. The three-terminal regulators are referenced to ground, and they draw some operating current (around 5 mA).

By placing a resistor(s) in the common ground lead, you can lift the common terminal above ground a few volts. We recommended using two resistors as shown and running about 15–20 mA through the voltage divider. By making R2 a pot, you can get an adjustable output voltage. Note that a zener diode can also be used here, and the regulated output will be 5 volts plus the zener diode voltage. However, remember that the regulator is designed to keep the voltage between its common terminal and output terminal dead constant, not the voltage between output and ground. You will get some small loss of regulation using this circuit, but for most applications it is not serious and saves money. Also, there will be no need to stock 8-volt units. You can get up to about 10 volts with excellent performance, although higher voltages are possible if some fall-off in regulation is allowable. For higher voltages (ouputs in the 12- to 24-volt range), use the LM7812—very common, cheap, and widely available. Again, it is a good idea to use a protection diode between input and output to guard against accidental reverse voltage, if this is a possibility.

Voltage In, Voltage Out

The LM723 has been around a long time and is one of the most widely used ICs for building power-supply regulators. By itself, the LM723 will handle up to 150 mA, with outputs from 2 to 37 volts. However, dissipation in the regulator is limited to 660 to 900 milliwatts, depending on the package. Figure 7 shows a typical application of this device as a 12-volt regulator for a small-bench power supply. The LM723 has an internal reference of nominally 7.15 ± 0.20 volts (± 0.35 V for LM723C version). By selecting a few resistors, you can program the output voltage to suit.

A power transistor is used to handle most of the output current, and a resistor in the emitter is used as a current-sensing device for current-limiting purposes. An internal transistor in the IC is turned on if this voltage drop exceeds about 0.6 volts, providing current-limiting action via internal circuitry. Capacitor C1 is a compensating capacitor that maintains loop stability. It is in the feedback network in the internal error amplifier, between output and the inverting input. Since the reference voltage is 7.15 nominal and is applied to the non-inverting input of the error amplifier, at equilibrium, the input to the inverting amplifier must also be very close to 7.15 volts (assuming high error amp gain).

Therefore, for 12-volt output, the voltage divider made up of R1 and R2 must provide 7.15 volts at the junction of R1 and R2. Resistor R2 is not critical, and almost any reasonable value can be used. For practical reasons, between 1 and 10K is usually used. Choosing 3.9K for R2 will require R1 to be 2.65K, and 2.7K is a close standard value. This divider will yield 12.1 volts, subject to reference voltage tolerance (about 5%). Resistor tolerances will add to this, so, in practice, using a 2.2K resistor in series with a 1K resistor for R1 will allow trimming of output voltage between 11.2 and 13 volts. Resistor R3 must provide 0.6 volts drop at 500 mA current-limiting, so a 1.2-ohm resistor is needed. In practice, a 1-ohm resistor will allow 600 mA maximum, giving a little extra margin. Component Q1 must be adequately heatsinked, since at 12 volts output and 20 volts input as much as 4.8 watts will be dissipated in Q1 (8 volts drop at a possible 600 mA).

Under full-load conditions (12V at 500 mA), with 20 volts DC in, 4 watts will be dissipated in Q1. A short-circuit on the output could produce 12-watts dissipation if the regulator input were 20 volts. This possibility must be considered if short-circuits are likely. Also, D1 is used to provide a way for energy stored in the load (capacitors, inductive spikes, accidental application of higher voltage due to component failures in load) to dump into the large input filter capacitor instead of the regulator. This situation can occur also when the DC input supply is shut down. Load regulation with the LM723C in this circuit should be 20 mV or better, no load to full load (500 mA), with about 2–3 mV change during a 5-volt change in input voltage (15 to 20 volts). As can be seen, a pretty good performance can be obtained with few components and a sim-

NORTH COUNTRY RADIO: A HAVEN FOR WIRELESS BUFFS

Graf and Sheets are no strangers to the pages of Gernsback. Their educational projects, such as the *RF-Field Strength Meter* and the *MPX2000* FM Transmitter, can be found at **North Country Radio**. Established in 1986, this company offers projects related to amateur TV transmitters/receivers, AM and FM transmitters/receivers, video cameras, and numerous other subjects. Visit the Web site at **www.northcountryradio.com** for more information.

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PO Box 200, Hartford, NY 12838
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e-mail: support@northcountryradio.com

ple circuit. We highly recommended consulting the manufacturer's application notes and data sheets (you can usually download these on their Web sites), as there are many other configurations and applications of these devices.

By using auxiliary power transistors and adequate heatsinking, you can construct power supplies delivering commonly used supply voltages (12, 24, or 32 volts) at up to 50 amps or more. However, remember that at these high power levels there may be considerable power dissipation in the regulator system, so the regulator should be operated at as low a voltage drop as possible consistent with minimum expected input voltages at maximum load. In variable voltage output regulators, the worst case is full load current at minimum output voltage, since this case produces the largest voltage drop and power dissipation in the pass transistors. One should always consider the possible use of switching supplies, which are more efficient and less bulky, at high (>25 watt) power levels. The tradeoff point is generally somewhere in the 10- to 100-watt range, but this is subject to various other considerations. The elimination of 50- or 60-Hz magnetics, large heat sinks, and cooling fans can greatly reduce cost and weight.

Also, a switching type pre-regulator before the main regulator can take some of the dissipation and heat load off the linear regulator. Another method, if the load is fairly constant, is to use a resistor across the regulator as shown in Fig. 8. Some of the load current passes through this resistor, reducing dissipation in the pass transistors. The total heat generated still remains the same, of course, but power resistors are less delicate than power transistors. The load must never be smaller than the current passing through the shunt resistor, or else the regulator will be cut off and the load voltage will rise above the desired voltage.

There is much more to power supplies than discussed here, but this information should prove a useful start for most hobbyist and experimenter power-supply requirements. These circuits can be built and experimented with, as there is no substitute for hands-on experience. The ability to design and build exactly what you need can be very useful and can save some money. P

Artificial Muscles

JAMES VAN LAARHOVEN

An arm wrestle with Mother Nature

What have been dubbed "Artificial Muscles" are actually specific polymers that perform a similar function. For many years, various polymers have been replacing conventional materials. Although we are all familiar with the use of these materials, there is, however, a new class of polymers that is displaying great promise. *E*lectro*a*ctive *P*olymer (EAP) research is an emerging science that could easily change the way many people live their lives. Along with the many useful commercial applications, the promising research and development now taking place in the field of electroactive polymers may be of great benefit to the handicapped. NASA is currently investigating and considering many EAP uses for space, including robotic arms, miniature rovers, and dust wipers—just to name a few. The applications for this material do indeed seem endless.

How Artificial Muscles Work. A series of different types of EAP materials have actually been around for quite some time. One of these polymers was previously used in fuel cells and in the production of hydrogen. In 1992, it was discovered that by reversing the charge/storage process, these polymers deformed when an electrical charge was applied, (see Fig. 1 for a wet-type EAP). The extent of potential deformation can exceed twice the original polymer shape in this type of EAP. In fact, the material can actually make a loop at maximum deformation levels. This large displacement is due to internal ion-exchange actuation by low-voltage—around 2–3 volts—and low frequency input—usually less than one Hz. The anode attracts the negative ions within the material while the positive ions gather near the negative, or ground source, electrode. This ion-exchange causes a bending action of the wet EAP material, which tends to move towards the anode. Figure 1 illustrates an IPMC (*I*on-exchange *P*olymer *M*embrane *C*omposite) type of EAP material. This kind of EAP can be composed of many different actuation materials. (See the "How To Make An Artificial Muscle" section for further discussion on these composites.) One IPMC type is made of a composite called perfluorocarboxylate-gold with tetra-n-butylammonium or lithium cations (cations are positive ions). This particular combination has shown much success in artificial muscle research and is currently being developed for application as a catheter guide for cardiovascular operations.

Longitudinal EAP Actuators. Figure 2 illustrates another type of electroactive polymer that displays longitudinal elongation. This dry-type polymer is generally rolled into a tube; when an electrostatic field is introduced, it expands in a linear fashion. When the electrostatic field is taken away, the material returns to its original length. EAPs of this type are actuated by Coulomb forces between electrodes to squeeze or stretch the material. This rope-like actuator acts very much like a biological muscle. The foreseeable uses for this material include prosthetics for the medical industry, along with many other assembly-type applications throughout the industrial market. Longitudinal EAP actuators are typically known as dry-types and usually require higher activation voltages (100 volts/micron) than the wet-type electroactive polymers. However, the material response time for the dry-types is rather quick, and they tend to react with a stronger force than their wet-type counterparts.

Using EAPs As Sensors. It is interesting to note that when certain types of electroactive polymers are physically flexed, they produce a voltage output. This effect allows EAPs to be used as potential sensors in various types of equipment. With EAP's inherent flexible and durable nature, long sensor life is expected.

Research. Research has unveiled many EAP discoveries such as polymer-ionic gels and improved polymer films. Each discovery is contributing to the overall scope and understanding of EAP materials.

The *J*et *P*ropulsion *L*aboratory (JPL) has committed extensive research and development time into improving the qualities of EAPs. Dr. Yoseph Bar-Cohen, from JPL, is one of the foremost researchers in the technology of Artificial Muscles. He has lead various groups

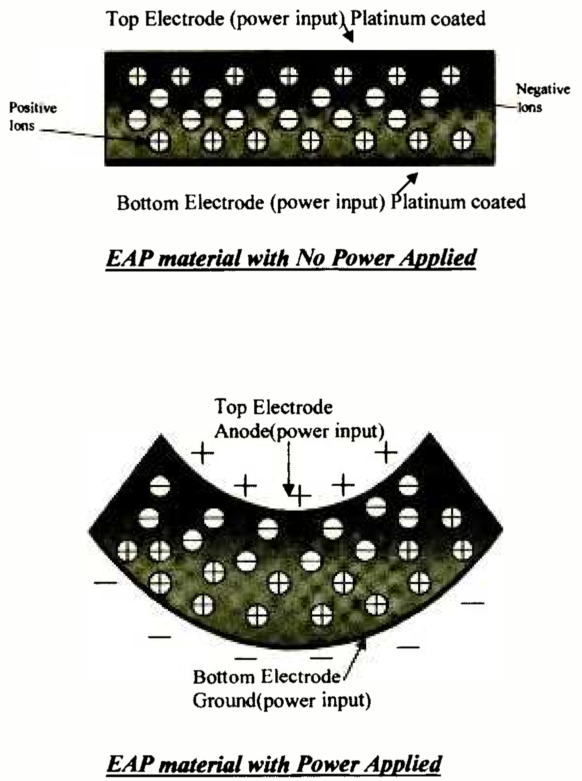

Figure 1
Wet-Type (bending) EAP (electroactive polymer) Material
Ion-Exchange Platinum-Membrane Composite (IPMC)

Fig. 1. Bending-type polymers need to be kept moist continuously in order to work properly. If this EAP is operated in open air without a sealing coating material, it would only work for few minutes. This sealing is different than the metallic layer that is used to provide power connection for the electric field.

in the search for improved EAP materials and their practical applications. Within these research groups, various mechanisms have already been created that demonstrate the true potential of electroactive polymers. Dr. Bar-Cohen says that new EAP applications in numerous fields are now being considered that could not be possible before.

One of the many practical items that Dr. Bar-Cohen and his researchers have developed is an IPMC wiper-blade assembly. This wiper assembly was considered for installation in the infrared camera window of a planetary nano-rover. The nano-rover will be used on the MUSES CN NASA/Japan expedition to a nearby asteroid in the year 2002. During the Viking and Mars Pathfinder mission, dust accumulation became a problem for the landing equipment. Implementing this EAP wiper assembly should reduce these dust particle problems.

EAPs And Robotics. Electroactive polymer materials will be useful in the field of robotics for muscle-type actuation. This includes large and micro-robotic assemblies.

"These materials are offering the potential of making many science fiction ideas into reality," says Dr. Bar-Cohen. "It will cover the range from making insect-like robots to superhuman augmentation."

A challenge has been given to the EAP science community to make a robotic hand capable of winning against a human in an arm-wrestling match. Numerous universities and corporations are rising to meet this interesting challenge.

"While we are still away from reaching the force levels that allows us to build a robot that can win an arm-wrestling match with a human, a lot of progress has been made in the last decade," adds Bar-Cohen.

Figure 3 displays a robotic arm that implements both wet- and dry-type EAP material for force actuation. This is not a completed arm assembly; however, it demonstrates a few possibilities for the future uses of electroactive polymers. The JPL has developed a working robotic arm that employs both wet and dry electroactive polymers, (see photo). Additional pictures of this arm and many other illustrations can be viewed on the JPL and NASA Web sites—one of which is *ndeaa.jpl.nasa.gov*. More information about EAPs can be found in a comprehensive book that was published in March 2001 by SPIE Press—The International Society for Optical Engineering. Dr. Bar-Cohen is the editor of this book, and more information about it can be found at *www.spie.org/bookstore/*.

EAP Comparison With Existing Actuator Technology. Of course, NASA is very interested in EAP actuator conversion because of the promise of reduced weight, bulk, and power consumption. NASA's interest is due mainly to the constraints in available space payload. However, the commercial market is also showing interest in EAPs for the potential replacement of inefficient actuating devices currently in use. Many actuation devices are constructed

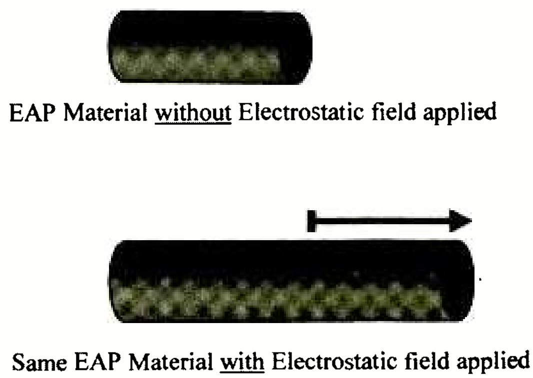

Figure 2
Longitudinally Activated Electrostatic Material
Dry-Type EAP

Fig. 2. An electrostatic actuator is commonly made as a capacitor with parallel electrodes that employ a thin air gap. In order to activate this rope-like actuator that was demonstrated by JPL, inputs of nearly 2000 volts may be required.

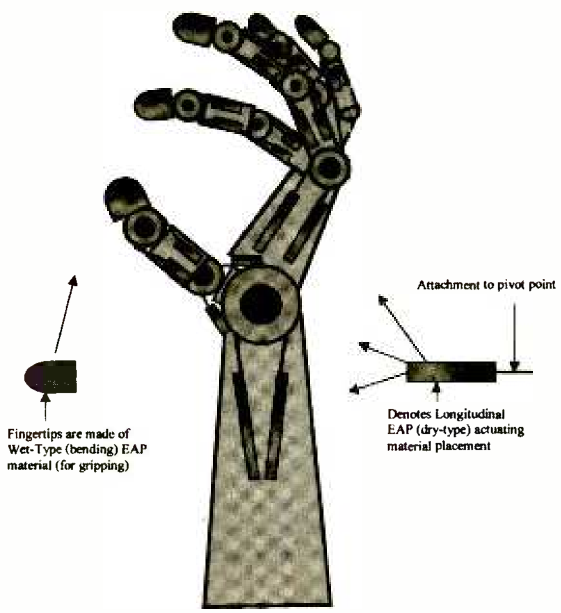

Figure 3
EAP Robotic Hand
(using Dry-type EAP material for longitudinal actuation and Wet-type bending EAP for fingertip gripping)

Fig. 3. Replacing bulky actuators with EAPs will allow future robotic equipment to be reduced in size. In addition, reduced EAP power requirements will also scale down the size of power supplies and control circuits.

with heavy metals and power-wasting coils. In addition, when these older-type actuators are implemented, they usually require large power supplies and bulky attachments to accommodate their normal operation. These attributes typically have made equipment far too cumbersome for many applications, and robotics is a good example of this. With the future transition to EAP-type actuators, much of this bulk could be reduced. Eventually, this trend would reduce the overall costs of robotics-related hardware and increase the capabilities of the equipment.

EAPs And The Handicapped. Because of the way artificial muscles work, they are referred to as biomimetic devices. Biomimetics denotes the imitation of biological functions or an outward appearance of the same. EAPs perform an excellent imitation of biological muscles since they lengthen and contract in much the same manner as a bundle of muscle fibers. EAPs may some day be a very good muscular replacement for many handicapped individuals because of these inherent similarities

Internal muscle replacement is a future possibility; however, external appendage assistance seems to be the next logical step for artificial muscle technology. Since biological muscles are quite strong, the force generated by future EAP materials will need to be greater than the materials now. EAP scientists are currently researching adequate force generation. Once this issue is resolved, EAPs may very well become a source of renewed movement for people with handicaps.

EAP Growth. While the progress in the field of electroactive polymers is very encouraging, there's a need for continued research to develop the true potential of these materials. Wet-type EAPs rely on ionic-action while the material is moist or immersed in fluid. This presents some unique operational problems. One of the challenges is to keep the material moist for extended periods of time, and another is to reduce the ill effects of electrolysis. Certain coatings are being developed that will help alleviate the moisture-loss problems, and reductions in the voltage input to the materials is cutting down on the degrading effects of electrolysis.

Another challenge that is facing EAP researchers is permanent material deformation. When DC voltages are introduced into certain wet-type EAPs for extended periods of time, the material sometimes does not return to its original shape. Currently, investigations are under way to counteract this permanent deformation problem.

How To Make An Artificial Muscle. Advances in EAP have been hampered somewhat by the lack of commercially available materials; therefore, most EAP materials need to be produced from scratch. As mentioned previously, one of the EAP materials is the IPMC membrane. These materials bend significantly under a relatively low activation voltage of about 1–5 volts and use fractions of watts for such bending.

The following is a preparation procedure for making IPMC. When attempting a project such as this, being familiar with the safe and proper use of chemicals is important. This procedure is outlined by Dr. Keisuke Oguro, who is one of the pioneers of the IPMC and a leading EAP scientist. Since IPMC technology is fairly new outside the scientific community, the procedure for producing it tends to be technical in nature (from a chemistry standpoint). If you are somewhat familiar with chemistry and can locate all of the required chemicals, it can be an interesting and rewarding project.

Note. These chemical compounds have complex names. Efforts were made to use common names for

JPL's robotic arm was built mainly to demonstrate how EAP technology could be used to collect planetary samples on future space missions.

MUSCLE RECIPE INGREDIENTS

(NOTE: Aqueous solution means that the chemical is dissolved in water. Pt is the element symbol for platinum.)

Base polymer membrane: Nafion 117 (purchase from DuPont distributors).

Aqueous solution of platinum ammine complex ((Pt(NH3)4)Cl2 or (Pt(NH3)6)Cl4). Either platinum complex can be used for this procedure, and it is used to form a metallic coating outside the Nafion 117 membrane and to form electrodes. These complexes can be purchased from Aldrich Chemical Co., Milwaukee, WI. Catalog #275905.

Sodium borohydride (NaBH4). This is a reducing agent needed for primary reduction.

Hydrazine hydrate (NH2NH2-~1.5H2O). 1.5 describes the quantity of water present in this compound. It should be purchased with the 1.5 water ratio. This compound is one of the reducing agents needed for secondary reduction.

Hydroxylamine hydrochloride (NH2OH-HCl). This is another reducing agent needed for secondary reduction.

Diluted ammonium hydroxide solution (NH4OH 5% solution). This 5% chemical solution should be purchased rather than personally prepared, and it is used during adsorption and secondary membrane plating.

Diluted hydrochloric acid (HCl aqueous, 2 N solution and 0.1 N solution). The 2 N and 0.1 N are descriptions of the concentration levels of this acid. 2 N and 0.1 N solutions should be purchased separately. This acid is used throughout the procedure.

Deionized water.

Fine glass beads (GP 105A, Toshiba Co.) or emery paper used to roughen the surface of the polymer membrane.

these chemicals, but there were none found. However, the companies that sell these chemicals will know what they are and also the concentration levels of each one mentioned in the procedure. The quantities of the chemicals that are needed depend on the size and number of membranes that you will process. These chemical quantities can be calculated by using the membrane sample described in the procedure.

Caution. It is dangerous to add $NaBH_4$ powder in a hot solution, because of the risk of gas explosion. So the recommended procedure is to add $NaBH_4$ solution to a cold solution and then to warm the solution using a water bath.

If any Pt ion remains in the plating solution, the color of the solution turns to black. In such a case, continue to develop Pt with addition of the hydroxylamine hydrochloride (NH_2OH-HCl) and hydrazine hydrate (NH_2NH_2) solutions. If you discover that there is no Pt ion in the chemical-plating solution, rinse the membrane with water and boil in a diluted hydrochloric acid (0.1 N) to remove the ammonium positive ions in the membrane. After it is washed with water, positive hydrogen ions in the composite can be exchanged by immersing in a solution of dilute hydrochloric acid.

Preparation Procedure. To prepare for this project, you will need to locate all of the required materials. The sidebar is a list compiled by Dr. Oguro. If some of the materials are hard to find, you may wish to consult with your local university chemistry department (or check the Web). When preparing the material, observe the caution listed above.

Procedure. Follow this procedure carefully.

Step I: Roughen the surface of the Nafion polymer membrane in order to increase the surface area of the polymer. A simple method is to use emery paper to sand the material. A preferable alternative method of surface roughening is to use a mild sandblasting procedure. For this purpose, use fine glass beads that are blown by compressed air onto the dry membrane. The speed of sandblasting is one second for every cm^2 of the membrane area.

Step II: Remove the glass beads by washing the membrane with water, preferably using an ultrasonic cleaner.

Step III: Treatment with HCl. Boil the membrane in dilute hydrochloric acid (using the HCl aqueous, 2N solution) for 30 minutes to remove impurities and ions from the membrane. Rinse it with deionized water.

Step IV: Treatment with water. Boil the membrane in deionized water for 30 minutes to remove acid and to swell the membrane. The roughened membrane can be stored in deionized water.

Step V: Ion-exchange (adsorption). Prepare a platinum complex ((Pt(NH_3)4)Cl2 or (Pt(NH_3)6)Cl_4) solution of two mg Pt/ml. This means that the quantity of platinum complex added to the solution has to be what is necessary to have two mg of platinum for every ml of solution (e.g. For a 45 ml solution, add 90 mg of platinum complex to 45 ml of water). Although the adsorbing amount depends on the charge of the platinum complex, either platinum complex will give good electrodes. Electrodes are the platinum films deposited on both the top and bottom of the EAP. These electrodes will be connected to a power source like a battery or other low-voltage supply. Immerse the membrane in the solution containing more than three mg of Pt per cm^2 membrane area. For instance, more than 45 ml of the Pt solution is required for a membrane of 30 cm^2. Excess amount of the Pt solution is preferable. After immersing the membrane, add one ml of ammonium hydroxide solution (5%) to neutralize. Keep the membrane in the solution at room temperature for more than three hours (one night usually).

Step VI: Primary plating (reduction). Prepare a five wt% aqueous solution of sodium borohydride. (This means that 5% of the total mass of the solution will be sodium borohydride and the rest will be water). After rinsing the membrane with water, place the 30-cm^2 membrane in 180 ml of stirring water and place in a water bath at 40 degrees C. Then, add two ml of the sodium borohydride solution (5 wt% $NaBH_4$ aqueous) every 30 minutes for seven times. The amount of the reagent should be proportional to the area of the membrane (meaning if you have a 60 cm^2 piece of membrane, use four ml). In the sequence of addition, raise the temperature up to 60 C° gradually. Then, add 20 ml of the reducing agent (sodium borohydride solution) and stir for an hour and a half at 60 C°. A black layer of fine Pt particles will deposit only on the surface of the membrane. Rinse the membrane with water and immerse it in dilute hydrochloric acid (use the 0.1 N solution) for an hour.

Step VII: Secondary plating (developing). The amount of platinum deposited by the first plating (reduction process) is less than 0.9 mg/cm^2—in other words, very thin. This thickness depends on the ion exchange capacity, thickness of the membrane, and the structure of the Pt complex. The developing process on the deposited Pt layer plates an additional amount of platinum during this part of the procedure. When you add two mg/cm^2 of Pt on the area of 60 cm^2 (both sides of 30 cm^2 of membrane), you need a Pt complex solution containing 120 mg of Pt. Prepare a 240 ml aqueous solution of the complex ($[Pt(NH_3)_4]Cl_2$ or $[Pt(NH_3)_6]Cl_4$) containing 120 mg of Pt and add five ml of the 5% ammonium hydroxide solution. Plating amount is determined by the content of Pt in the solution. Prepare a 5% aqueous solution of hydroxylamine hydrochloride (NH_2OH-HCl—5% chemical and the rest water) and a 20% solution of hydrazine hydrate (NH_2NH_2—20% chemical and the rest water). Place the membrane in the stirring Pt solution at 40 C° and add six ml of the hydroxylamine hydrochloride solution and three ml of the hydrazine solution every 30 minutes. In the sequence of addition, raise the temperature up to 60 C° gradually for four hours; and gray metallic layers will form.

At the end of this process, sample a small amount of the solution and boil it with the strong reducing agent sodium borohydride ($NaBH_4$) to check the end point (observe the cautionary remarks that were described earlier). The end point refers to the point at which the color of the solution change.

The Future. Overall, the future of electroactive polymers is very promising. Worldwide response in regard to their further research and use is positive. Institutions, universities, and corporations are all making useful contributions to ensure EAP's inevitable success. In some ways, EAP research is comparable to the space program during the 50s and 60s—many said that a trip to the moon was impossible. This goal not only became a reality, but it brought a sense of pride along with it. In the same regard, if the use of EAPs could make handicapped people literally "not handicapped," it would unarguably be a great accomplishment—an accomplishment that could dwarf many others of our technological era. P

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BUILD A SMART FLASHLIGHT

ROBERT NANCE DEE

The power's out again! Don't worry—with this one-night project, there's always light on hand.

Although power failures are common in the rural area where I live, we are not always fully prepared for them. One moonless, overcast night, while I was working on a project in my shop, the power suddenly went out. There I was, in a pitch-black room full of tools and clutter. I started thinking that it would be nice to have a light that flashed when the power went out, so that I could easily find it and then be able to find my way around. This device seemed so useful, I decided to build one of my own.

The *Smart Flashlight* blinks when the power goes out. By blinking, it saves battery power; and if the power comes back on or the sun comes up, the flashlight

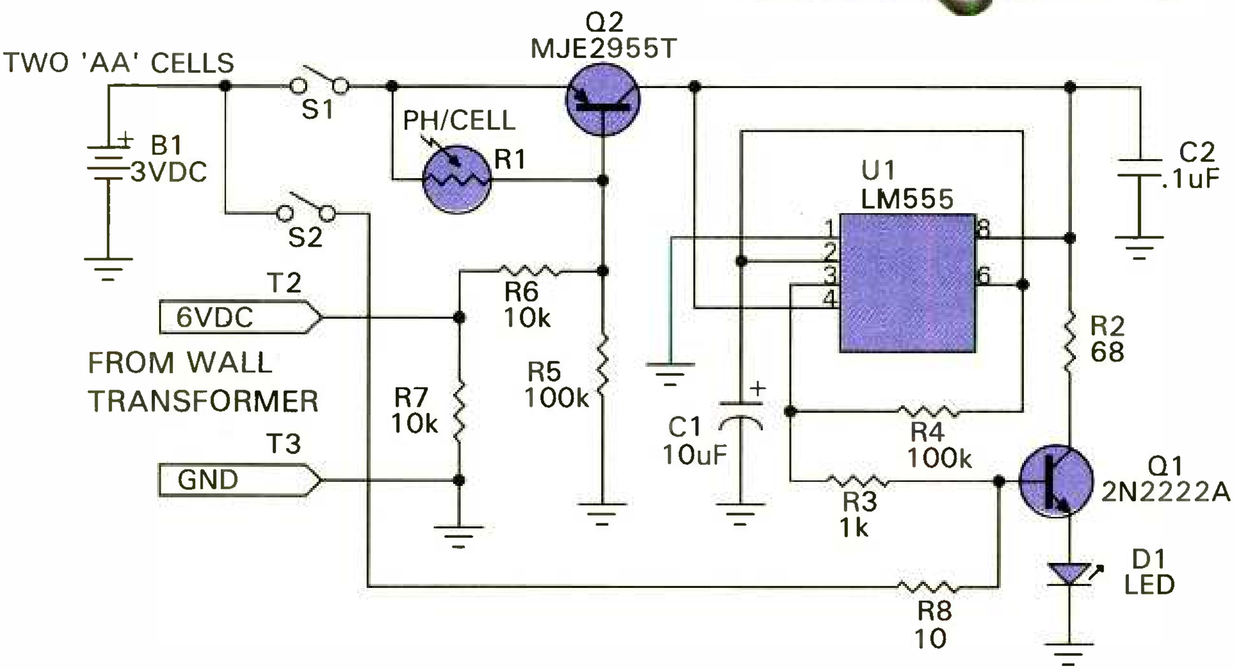


Fig. 1. This is the schematic for the Smart Flashlight. Photoresistor R1's resistance increases as the light hitting it dims. This result drops the voltage on the base of Q2, turning it on and supplying power to U1, the 555 timer.

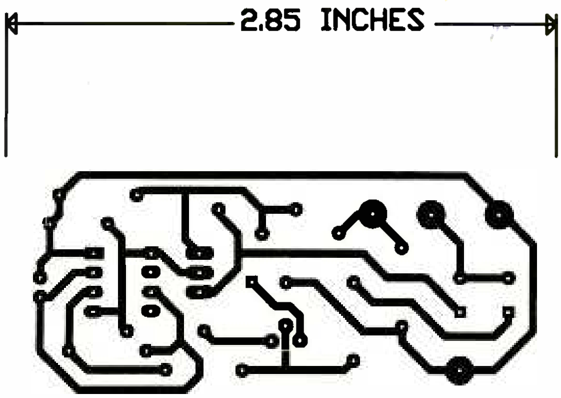
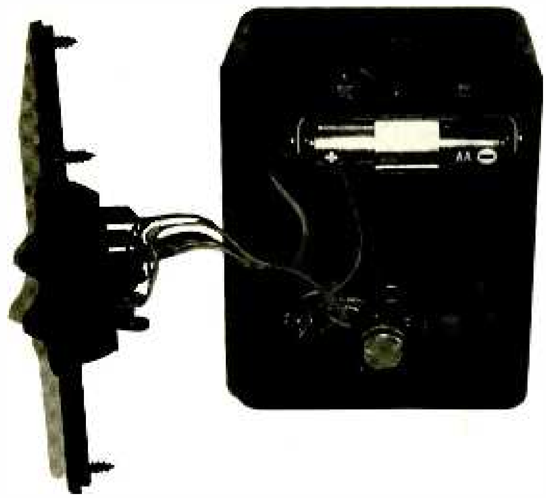


Fig. 2. The printed-circuit board has been dimensioned to fit vertically and crosswise in the slots of a 3- × 4- inch plastic box. The foil pattern above can be used to create your own PCB.



turns off. It's the perfect solution for finding standard flashlights or other long-term lighting during a power outage.

Operation. Follow along with the schematic in Fig. 1 as you read this section on the theory of operation. Two 1.5-volt AA batteries in series supply 3 volts to Q2, through the main-power switch S1. Photoresistor R1's resistance increases as the light hitting it dims. This result drops the voltage on the base of Q2, turning it on and supplying power to U1, the 555 timer. Should the power from the wall transformer to the 6-V_{DC} input be high—indicating 120-volt AC line power, R6 biases Q2 high and shuts off the circuit.

The timing circuit of U1, made up of R4 and C1, sends a 700-millisecond pulse to Q1 through R3, which drives the high-brightness LED, D1, on and off.

Turning switch S2 on while switch S1 is either on or off applies a high to Q1, which turns on D1.

Construction. The circuit layout is not critical; and while I made a PC-board layout for neatness, a breadboard will work just as well. The printed-circuit board (see Fig. 2) has been dimensioned to fit vertically and crosswise in the slots of a 3- × 4- inch plastic box. Should you decide to breadboard the circuit, you might want to consider keeping the board dimensions the same as they make a very neat project. I mounted the two AA cells on a piece of circuit board that also fits the case slots. Use Fig. 3 as a reference when you install the components.

The phototransistor is not critical. I measured the

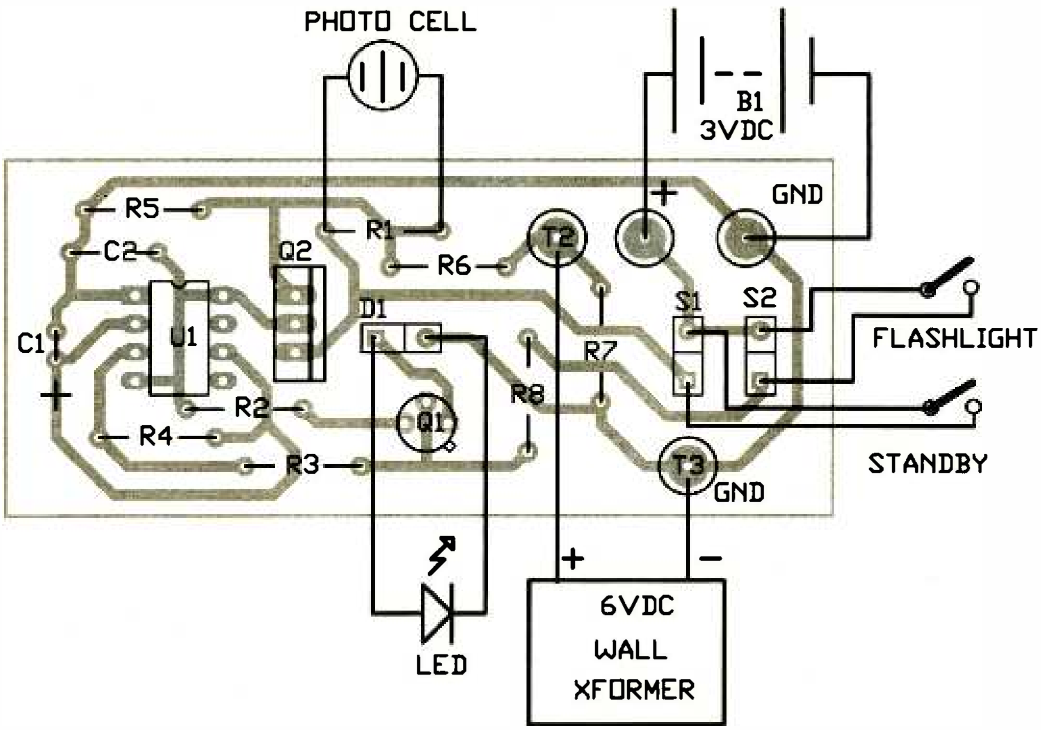


Fig. 3. The circuit layout is not critical; and while the author made a PC-board layout for neatness, a breadboard works just as well. This parts layout diagram should be used as a guide when constructing your own unit.

PARTS LIST FOR THE SMART FLASHLIGHT

SEMICONDUCTORS
U1—LM555
Q1—2N2222A
Q2—MJE2955T
D1—Light-emitting diode, any color, high-power

RESISTORS
(All resistors are ¼ watt, unless otherwise noted.)
R1—Photo cell
R2—68-ohm
R3—1000-ohm
R4, R5—100,000 ohm
R6, R7—10,000-ohm
R8—10-ohm

CAPACITORS
C1—10-µF
C2—.1-µF

ADDITIONAL PARTS AND MATERIALS
S1, S2—Switch, rocker style or SPST-toggle
T2, T3—PCB-mounted test pin
3- × 4- × 1¼- inch plastic box, 6-V_{DC} wall-mounted power-supply, power-supply jack, PCB, two AA batteries, battery holder, hardware, wire.

An etched and screened PC board is available from Design Specialties, 4444 County Hwy. 16, Delhi, NY, 13753-9737 for $9 plus $3 shipping and handling. NY residents must add appropriate sales tax. E-mail: euclid@catskill.net.

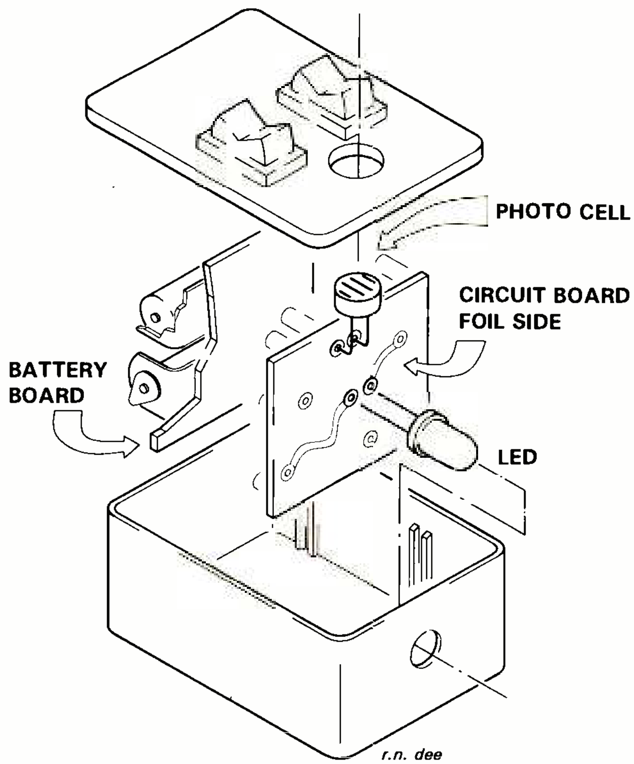


Fig. 4. This is an exploded-view diagram of the entire device fitting into a project case. Note the hole for the LED on the case and the hole for the photo cell on the lid.

dark resistance of mine at 1 megohm and at about 500 ohms with a light on its face. Should Q2 not turn on or off with your photoresistor, change the value of R5 until it turns on when you cover the photoresistor's face with your hand. (See the "Testing" section for more details.)

I used a jumbo LED (604-I813SRCE, Mouser Electronics), but the jumbo LEDs from RadioShack will work fine. Whichever you choose, make sure it has a 1.8- to 2.5-volt working range.

The wall transformer is a standard 6-V_{DC} supply, and the power required is very small—the lowest current transformer you can find will work. Make sure the positive lead goes to terminal T2 and the negative lead goes to ground. You might want to add a plug directly on to the case, which would enable you to remove the wall transformer. (Figure 4 shows an exploded-view diagram of the entire project fitting into a standard project case.)

I used two rocker switches for my circuit, but you may decide to use toggle switches. The MJE2955T transistor, Q2, does not need a heat sink. However, make sure the metal tab on its case doesn't touch any bare wires. Use a high quality transistor for Q1, with a metal case. The TO-18 package, 2N2222A, works best.

Testing. Turn on switch S1, with the batteries in place, and cover the face of photoresistor R1. The LED should blink on and off slightly faster than one pulse per second. Should you wish to increase the flashing rate, decrease the value of R4. If the LED doesn't light, check to see if pin 8 of U1 has a steady 2.9-V_{DC} on it. If not, Q2 is not turning on; and R5 may have to be changed to a lower value. Should the LED flash even when well lit, increase the value of R5.

With S2 closed, regardless of the state of S1, the LED should light continuously. Turning S1 to the off position disables the flashlight's sensing and flashing abilities, but not its standard flashlight circuit.

Now, connect the 6-V_{DC} adapter to pin T2. With S1 on and S2 off, the LED should be off. Cover the photoresistor; the LED should remain off. Keep the photoresistor covered and disconnect the adapter. The LED should start to blink.

The current through the two AA cells measures about 12 to 14 milliamps with the LED flashing and 23 milliamps with the LED on constantly. With these figures, alkaline batteries should last a very long time. In normal standby operation, S1 is on and S2 is off. Checking the batteries from time to time only requires a flip of switch S2.

With this easy-to-build project, you should never be left in the dark again. **P**

JOHN HAYS HAMMOND, JR. "THE FATHER OF THE REMOTE CONTROL"

MARIA ORLANDO

John Hays Hammond, Jr. was a prominent inventor, distinguished engineer, and a renowned world traveler and socialite. He pursued a variety of interests, a smorgasbord of arts and science, if you will. His passions covered the spectrum of electronics, torpedoes, communications, music, cooking, and the collecting of Medieval art. He is credited with over 800 inventions and 437 patents (second only to Thomas Edison); his most noted work was the development of remote control via radio waves, which earned him the title "The Father of the Remote Control."

A Star Is Born. Born into an affluent family in 1888, he lived in San Francisco for five years until his family moved halfway around the world to South Africa, where his father was an engineer in the diamond mines.

The Hammonds returned to the United States at the turn of the century, and John Hays Hammond, Jr. then began his life as an inventor at the Lawrenceville School in New Jersey in 1903. His very first idea, though sly, was very clever. It was a sensor and circuit breaker he built into the door of his dorm room, which shut the lights automatically when the door opened. This device allowed the students to elude the school's "lights out" rule at 8 p.m. sharp. At the time he was proud of his cleverness and ingenuity, but he later regretted not patenting the idea—years later the same kind of device was widely used in refrigerators and cars. Later in Hammond's career, Thomas Edison is said to have warned him of the consequences of failing to patent his work.

To further his education, Hammond studied at the Sheffield School of

Yale University; and it was there that he first encountered Alexander Graham Bell. While in school, Hammond concentrated on telephony and radio-dynamics until he graduated in 1910. Despite his family's prestige and fortune, he decided to take a modest position as a clerk at the U.S. Patent Office.

He helped launch this country's success in the world of technology.

He worked directly under Bell, and through the routines of every day operations, he gained insight into the direction and future of technological advances.

It was through this first-hand knowledge of new patents that he gathered sufficient resources and information to venture out on his

own. John persuaded his father to back him financially so that he could start his own business—and the Hammond Radio Research Corporation was established in 1911 in Gloucester, MA.

Ghost Ships And Remote Control. Gloucester was, and still is, a nautical fishing town. It is set on a harbor that opens up to the Atlantic (the actual events of *The Perfect Storm*, a well-known book and movie, took place there), and it served as an ideal setting for his newfound interest in radio-operated remote control of boats. In 1914, he sent his 44-foot ship—without a pilot or anyone else aboard—on a 120-mile "ghost trip" from Gloucester to Boston and back again. He did this by incorporating a gyroscope into a receiving system of the ship. He also added an anti-interference feature that would prevent jamming of the ship's signals, as well as inventing a target-seeking system that let a remote-controlled ship "sniff out" an enemy's searchlight. This invention was the catalyst for his next mission—the development of the first radio-guided torpedo.

At the time, World War I was under way. The U.S. military was very intrigued by Hammond's accomplishments, and he successfully demonstrated a radio-controlled torpedo system for the navy in 1918. By this time, the inventor had over 100 patents under his belt, along with the appreciation of the U.S. War Department.

When the war was over, Hammond shifted his focus to radio transmissions. Considered a pioneer in frequency modulation, he did extensive research in radio communications and technology.

Some of the inventions he

A SAMPLING OF HAMMOND'S PATENTS

1919	System of Teledynamic Control
1922	Altitude Determining System for Airplanes
1922	System for Radio Control of Moving Bodies
1928	Gaseous Detector of Radiant Energy
1929	Submarine Sound Transmission
1929	Cosmic Ray Detector
1933	Synchronization of Motion Pictures and Music
1936	Paravane Torpedo

VISITING HAMMOND"S CASTLE

Readers who want to see the museum at Hammond's Castle can contact the curators at 978-283-7673. The museum is in Gloucester, Massachusetts. The medieval-style castle features art and artifacts from the period, as well as photographs and possessions of John Hays Hammond, Jr. and his wife, Irene. You can also get a glimpse of the castle by pointing your browser to *www. hammondcastle.org*.

patented during his radio days included the single-dial radio tuner, a radio-alarm system, and a multichannel radio system. Hammond also served as an officer for The Institute of Radio Engineers, which standardized methods of testing and helped advance and disseminate knowledge regarding radio engineering and technology.

Hugo Gernsback (remember him? he's the founder of this publication) had alluded to Hammond in an editorial written in 1922. He said: "The radio-controlled airplane works very similarly to a radio-controlled ship. ...As a matter of fact, John Hays Hammond, Jr. ...has done this very thing. Radio-controlled planes will play a great role in the next war."

John Hays Hammond, Jr. was honored repeatedly for his achievements and hard work. In 1959, he received the Elliot Cresson Medal from the Franklin Institute in Philadelphia; and in 1962 and 1963 he was awarded the Medal of Honor from the Institute of Radio Engineers. He died on February 12, 1965, in Gloucester, where he is buried.

The Magic Of History. There is a fascinating personal side to the late John Hays Hammond, Jr. Though some considered him eccentric and odd, his story is somewhat magical.

In 1926, John Hays Hammond, Jr. built a medieval, gothic-style castle, known as the Hammond Castle. He and his wife Irene filled their new home with a vast collection of Roman, Medieval, and Renaissance artifacts they had collected on extensive journeys through Europe. He was enthralled with history and stories of long ago.

"For the last three years I motored many miles through Europe. After travelling all day, I would arrive at my destination to see a church, a cathedral, a town hall, a scrap of Roman wall or viaduct, a coliseum or ancient theatre. It was always a piece of architecture that suddenly dissipated the obscurity of time and brought the living presence back of all ages. It is in the stones and wood that the personal record of man comes down to us. We call it atmosphere, this indescribable something that still haunts old monuments. You can read history, you can visit a hundred museums containing their handiwork, but nothing can reincarnate their spirit except to walk through rooms in which they have lived and through the scenes that were the background of their lives. It is a marvelous thing, this expression of human ideals in walls and windows."

His castle also served as a lab and place of business, and it was where much of his work was done. The Hammond Castle still stands today, and visitors are welcome to explore the living quarters, inventions exhibit, tower galleries, and spectacular view of the Atlantic shoreline.

Myths, Legends, And Funny Business. Now is the time to bring up a controversial question: Once and for all, who invented the Hammond Organ? Was it John Hays Hammond, Jr. or Laurens Hammond? The answer to that, unfortunately, still isn't clear. Many sources point to the late Laurens Hammond as the true inventor of the Hammond Organ. It seems easy to confuse the two, since they lived in same era, were both inventor-engineers who worked on similar projects, and have identical surnames. (There is some reason to believe that they may have been acquainted or even indirectly related due to common ancestors in Scotland.) Most of the evidence points to Laurens Hammond as the real organ inventor. Neither one is here to defend himself, so we will put the issue to rest until there are further facts uncovered. For more details on this heated debate, readers can visit *www.the atreor gans.com*.

(Continued on page 54)

Only the Shadow Knows!

Q *I collect old AM radios and old radio shows. I would like to build a transmitter to broadcast some of these shows so I could receive them on my old radios. Do you have or know of any old projects from* **Popular Electronics** *or other magazines that show such a circuit? This could make a great project for* **Poptronics**' *"Basic Circuitry" column.—J.O., Haddonfield, NJ*

A You want an OLD project? Back in the 1960s, I built **Popular Electronics'** "Wireless Rebroadcaster." It was one of those wonderful projects that worked beautifully from the instant I turned on the power switch. Bass response from that circuit was wonderful, an important consideration for the old console radios with their rich bass. That circuit, which uses a single 12AT7 dual-triode vacuum tube, started on page 47 of the January 1965 issue with an "Out of Tune" correction in the March issue.

The schematic of the Wireless Rebroadcaster from the article originally written by Ken Dobler, is shown in Fig. 1. I've taken the liberty of including the later corrections. Note that this circuit was designed before capacitor values were standardized to the EIA values, so you may have to change the values of C5 and C6 to 390 picofarads, C1A to 47 microfarads, and C1B to 33 microfarads. Capacitors C1A and B may, of course, be separate capacitors rather than a dual unit as originally specified. Component L1 was listed as a "Miller 71-OSC" or equivalent.

More recently, Craig Kendrick Sellen submitted a transmitter that was published in the November 1998 issue of **Popular Electronics** on page 58. You should still be able to obtain that back issue from the source in the sidebar.

I'm only mentioning transmitters using vacuum tubes, as I've found that most antique radio buffs prefer those over solid-state circuits.

I bought a pair of quadraphonic (4-channel) reel-to-reel tape decks a few years before quad died a horrible death. I always wanted to build an 8-frequency transmitter, record old radio shows on all four tracks of two tapes, and transmit them simultaneously. That way, you could go around the house and amaze your friends as you tune in one old radio show after another on your antique radios.

In case you aren't aware of it, one of the finest and most insightfully crafted forums on the Internet is the Antique Radio Forum, owned and operated by Alan Voorhees. You'll find it at *www.antiqueradios.com*.

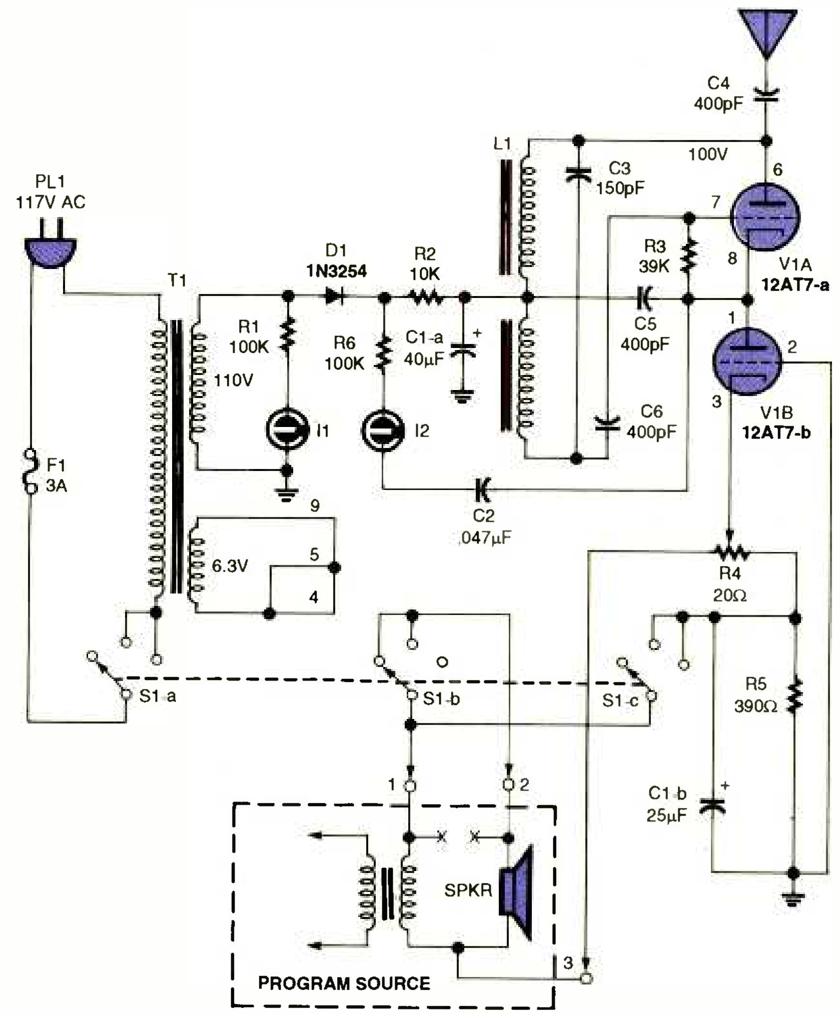


Fig. 1. The "Wireless Rebroadcaster," originally published in the January 1965 issue of **Popular Electronics**, *is an excellent low-power AM broadcast-band transmitter.*

"Rippling The Caps" With Decibels

Q *The above-captioned item in your November issue is misleading; and I think that you should have referred your readers to a course in RC circuitry available in the* ARRL Handbook 2001, *mentioned in your sidebar. For example: (1) The output of any rectifier is all ripple. (2) A filter capacitor is used to store the energy during this rippling and provide a steady DC voltage. (3) You can't add reactance and resistance together and say the sum is resistance. (4) Capacitive reactance does not turn current into heat; the energy is stored in a charge. Also, I think that 33 microfarads is a pretty small value for a filter capacitor unless very little current is drawn by the load. Many of your readers subscribe since they want to learn about electronics concepts. You owe it to them to be factual about these*

Electricity 101 concepts. Also, it might have been informative to mention in the item "Decibels and Gain" that while a doubling of power leads to a 3dB gain, in the case of voltage or current, it is 6dB. Keep up the good work, otherwise!— Kalle Naelapea, via e-mial

A Thanks for the feedback. Here's my response.

(1) Actually, if you look at the output of a 3-phase rectifier, you'll find that it is a healthy combination of both direct current and ripple. In fact, its output without filtering is much like the output of the more commonly known full-wave power supply with poor filtering. The three-phase rectifier is more common than you might think, because you'll find one in most automotive alternators.

(2) Yes, that's exactly what a filter capacitor does when looking at it from a charge/discharge perspective. You can also look at it as a low-pass RC filter, especially when it is used for decoupling or in a pi-network filter, as shown in Fig. 2. There, the cut-off frequency of the filter is very low, shunting nearly all the AC to ground and passing all the DC to the load.

(3) Kalle, in my answer, I DID caution the readers that in the real world, you can't just add resistance to reactance to get impedance. Near the end of my answer, it was explained that I was doing that for the illustration just to keep the math simple so that we didn't have to get into an Electronics 101 AC course. In reality, to find the current in the circuit, we would have to take the square root of the sum of the squares of the ESR and the capacitive reactance to get the impedance. This impedance divided into the AC ripple voltage would get us the current, and that current squared times the ESR would give us the power dissipated by the ESR as heat. With 33 microfarads and 10 ohms of ESR with 5 volts rms ripple, the correct impedance would be 41.4 ohms with 146 milliwatts of power dissipated in the ESR. With the impedance erroneously figured as 50.2 ohms, the power dissipated by the ESR would be 99 milliwatts. The idea wasn't to show phase relationships, but just the fact that power is indeed dissipated in ESR and that it can be problem with older capacitors. Sometimes they just open and fade away. Other times, they develop high ESR and burst.

(4) I also disclosed that a perfect capacitor consumes no true power when I said that "any power that is apparently

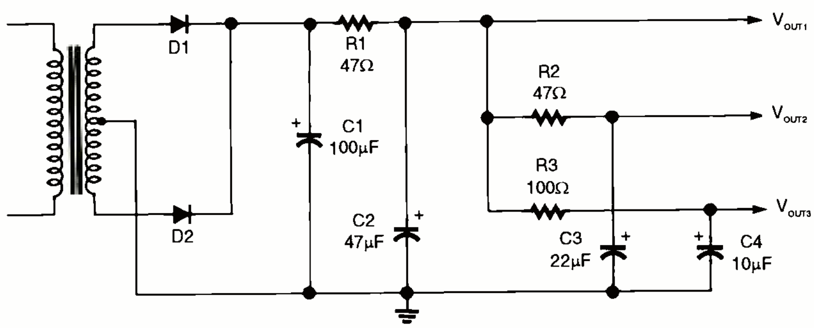


Fig. 2. Operating as a low-pass filter, RC networks are commonly used for power supply decoupling and filtering in audio amplifiers and test instruments.

'consumed' by the cap is just dumped back into the circuit at a later date, so no power is actually consumed." Only the ESR will dissipate power as heat.

Yes, 33 microfarads might be small; but, as you said, it depends upon the application. Values of 10 through 50 microfarads were the filter caps of choice in vacuum tube radios for 40 years! I chose 33 microfarads because it was a simpler number to put into print than was 680,000 microfarads. If 33 microfarads is too small for the supply in question, then it would make a perfect example of how ESR could cause major problems. A high ESR in a high-ripple situation like that would certainly cause the cap to vent or, worse, to burst.

Of course, you are correct that while a doubling of power causes a 3dB increase, a doubling of voltage or current causes a 6dB increase. This is because the value of voltage or current is squared when you use them with resistance to calculate power. When dealing with power, the decibel gain or loss is 10 times the log of the power ratio while the decibel gain or loss is 20 times the log of the voltage or current ratio. I suppose that I didn't mention that in my answer because I was playing with radio station output power.

Secret Codes

Q *I won't say how old I am, but I grew up with "Carl & Jerry" and have always loved electronics as a hobby and as a profession. One of the most important things I learned about electronics is to always carefully examine the schematic of projects and try to understand how and why the author did his design. There are some people who have commented that there should be no microprocessor (i.e., PIC) projects in an electronics magazine, but, to me, a PIC or other microprocessor is still "hardware." Not all projects should use micros, but if a five-dollar, 8-pin device will replace 10 discrete chips, why not? It's like saying that we shouldn't use ICs. The nice thing about a micro is that it's a lot easier to change a line of code than to go through a complete PCB design cycle when you have to make changes and upgrades.*

The point I'm trying to make is that in the December 2001 issue, you had a project for a mousetrap using a PIC. I don't have a mouse problem; but had it been available, I would have looked at the author's source code and asked myself if I would have done it differently and probably learned something from his approach. He used a 12C671, which I have never played with before; and his code would have helped me understand how to initialize the chip and get started doing simple programming. Leaving out the source code is no different than leaving out the schematic and defeats the whole purpose of your magazine. It doesn't have to be printed in the story. Publishing it on the Internet is fine. I have no serious complaints about your magazine and think you are doing a good job of keeping a balance of material. (Thanks for listening.)—M.M., Pembroke, Ontario

A For our newer readers, "Carl & Jerry" was a monthly electronics-related series of short stories that ran in **Popular Electronics** back in the 60s, usually centered around some mystery or stunt in which the two main characters were involved.

Perhaps many folks object to the microprocessor-based projects because they don't have the necessary hardware to get started and don't have the cash to invest in such things. Much of it may be a simple lack of knowledge. Others our age may be wary of a microprocessor invasion. We can remember the time when the new personal computer frenzy of the late 70s and 80s saw some general-electronics hobbyist magazines devote the bulk of their content to that subject, changing the entire look and thrust of the magazine and scaring off a lot of readers in the process.

I agree that simpler implementations of complex circuits can be better. On the other hand, I have thousands of TTL ICs at my disposal and would build a digital clock or a frequency counter using them rather than using a PIC, just because I have them and don't have to invest in any new parts. Of course, I'll pay for that attitude with a lot of circuit-board real estate and heavier power supply demands! As with amateur radio operators of the past, many of today's hobbyists survive on their junkbox, which has pre-PIC components as its source. They want to build things with what they already have. As you say, a balance is needed to satisfy everyone; and sometimes the teeter-totter gets a little heavier on one end. As you seem to indicate, it works out in the long run.

You are 100% right about the source code. Half of the project is the hardware and half is the software. Without either, the project is useless. In fact, the source code is the most important part of the project with respect to the learning potential. The hardware is often straightforward, while unique software puts the personality into the project. I'm assuming that there was an oversight in providing the source code for this project either in the printed article or on the **Poptronics** Web site and that a correction will be forthcoming. To have the code available only in preprogrammed PIC form not only creates a single-source for the main component, but renders the project nearly impossible to build if the preprogrammed PIC source disappears from the face of the planet. Hopefully, as our editors read this material, they'll make a note to insist that authors in future always supply the code so that it can be made available to readers in some form or other.

HOW TO GET INFORMATION ABOUT ELECTRONICS

On the Internet: See our Web site at *www.poptronics.com* for information and files relating to **Poptronics** and our former magazines (**Electronics Now** and **Popular Electronics**) and links to other useful sites.

To discuss electronics with your fellow enthusiasts, visit the newsgroups *sci.electronics.repair, sci.electronics.components, sci.electronics.design*, and *rec.radio.amateur.homebrew*. "For sale" messages are permitted only in *rec.radio.swap* and *misc.industry.electronics.marketplace*.

Many electronic component manufacturers have Web pages; see the directory at *www.hitex.com/chipdir/*, or try addresses such as *www.ti.com* and *www.motorola.com* (substituting any company's name or abbreviation as appropriate). Many IC data sheets can be viewed online: *www.questlink.com* features IC data sheets and gives you the ability to buy many of the ICs in small quantities using a credit card. You can also get detailed IC information from *www.icmaster.com*, which is now free of charge although it formerly required a subscription. Extensive information about how to repair consumer electronic devices and computers can be found at *www.repair faq.org*

Books: Several good introductory electronics books are available at RadioShack, including one on building power supplies.

An excellent general electronics textbook is *The Art of Electronics*, by Paul Horowitz and Winfield Hill, available from the publisher (Cambridge University Press, 800-872-7423) or on special order through any bookstore. Its 1125 pages are full of information on how to build working circuits, with a minimum of mathematics.

Also indispensable is *The ARRL Handbook for Radio Amateurs*, comprising over 1000 pages of theory, radio circuits, and ready-to-build projects, available from the American Radio Relay League, Newington, CT 06111, and from ham-radio equipment dealers.

Back issues: Copies of back issues of and past articles in **Electronics Now, Popular Electronics,** and **Poptronics** can be ordered on an "as available basis" from Claggk, Inc., Reprint Department, P.O. Box 12162, Hauppauge, NY 11788; Tel: 631-592-6721. To ensure receipt of the correct material, readers must supply complete information on the article or issue that they wish to buy.

Poptronics and many other magazines are indexed in the *Reader's Guide to Periodical Literature,* available at your public library. Copies of articles in other magazines can be obtained through your public library's interlibrary loan service; expect to pay about 30 cents a page.

Service manuals: Manuals for radios, TVs, VCRs, audio equipment, and some computers are available from Howard W. Sams & Co., Indianapolis, IN 46214; (800-428-7267). The free Sams catalog also lists addresses of manufacturers and parts dealers. Even if an item isn't listed in the catalog, it pays to call Sams; they may have a schematic on file which they can copy for you.

Manuals for older test equipment and ham radio gear are available from Hi Manuals, PO Box 802, Council Bluffs, IA 51502, and Manuals Plus, 130 N. Cutler Dr., N. Salt Lake, UT 84054.

Replacement semiconductors: Replacement transistors, ICs, and other semiconductors, marketed by Philips ECG, NTE, and Thomson (SK), are available through most parts dealers (including RadioShack on special order). The ECG, NTE, and SK lines contain a few hundred parts that substitute for many thousands of others; a directory (supplied as a large book and on diskette) tells you which one to use. NTE numbers usually match ECG; SK numbers are different.

Remember that the "2S" in a Japanese type number is usually omitted; a transistor marked D945 is actually a 2SD945.

Hamfests (swap meets) and local organizations: These can be located by writing to the American Radio Relay League, Newington, CT 06111; (*www.arrl.org*). A hamfest is an excellent place to pick up used test equipment, older parts, and other items at bargain prices, as well as to meet your fellow electronics enthusiasts—both amateur and professional.

Sorry, Mr. DeMorgan!

As I mentioned last month, Fig. 2 was the first thing to catch my eye when I first saw the November 2001 edition of "Q & A." My DeMorgan gate ended up with a "Face Off"-style "switcheroo" somewhere between oft-sent e-mail and offset press. The truth table is OK. The AND-with-inverted-inputs that was printed for the gate is actually a DeMorgan NOR. The illustration that should be there is an OR-with-inverted-inputs. Here's another way to look at it. It will have the proper logic of "if input A is low OR input B is low, then the output will go high; in all other cases, the output will be low," which will match the truth table for the NAND. Thanks to readers Howard Sharp, Mike Smith, James Nisly and Henri Joyaux for their swift, yet kind, finger-pointing in this direction.

Henri observed that "NAND" and "NOR" for "AND-NOT" and "NOR-NOT" seem odd substitutions, surmising that perhaps ANDNT and ORNT were too difficult to pronounce. I don't know. Doesn't ANDn't and ORn't roll off the tongue fairly easily? Aren't contractions made to roll? In these parts, contractions are a way of life. "If ya'll'd've called, we'd've gone with you." ANDn't and ORn't seem kind of natural to me. Time to rewrite my digital curriculum.

Op-Amp Impedances

Q *When it comes to impedance pertaining to series and parallel electronic circuits, I understand the subject fairly well. I've been an electronics experimenter and an amateur radio operator for 34 years. However, when it comes to op-amps, I do get lost in trying to understand some of the terminology associat-*

ed with them. For example, if I have an op-amp with an output impedance of 0.3 ohms or perhaps 1 megohm, what exactly does it mean? Your magazine has been providing articles concerning op-amps throughout the years, but hasn't explained various details. Can you provide me with a practical example of when this op-amp, with 0.3 ohms or 1 megohm, would be used? What could be tied to the output?—T.T., via e-mail

A A perfect op-amp has infinite input impedance, zero output impedance, infinite bandwidth, and zero offset current and voltage. A perfect op-amp doesn't exist; and, in reality, a perfect one might end up being very difficult to use since all that bandwidth would just contribute noise to low-frequency applications.

A typical general-purpose op-amp such as the venerable 741 has an input resistance of around 2 megohms. As illustrated in Fig. 3, the input impedance can be seen as a resistance from the input pin to ground, much like the 50-ohm input impedance of a linear amplifier. External circuits with resistance higher than 2 megohms can be affected by the input impedance of the op-amp, so we have to design our circuit around the op-amp using lower resistance values that won't be swamped by the input impedance. The various gain equations for the basic op-amp circuits are written with this assumption. If this assumption is incorrect, those equations will begin to give us incorrect values.

The output impedance is like the internal resistance of any source, whether a battery, function generator or transmitter output. It can be viewed as a resistance in series with a perfect source, as shown in Fig. 4. The output impedance of the 741 is very low, although it can only source a maximum of about 25 milliamps. A 1-megohm output impedance would be very impractical; from your letter, I can assume that you would

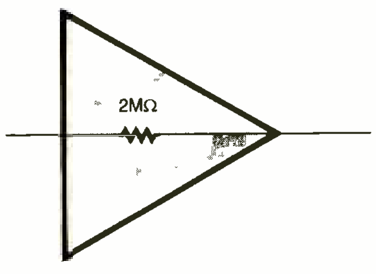


Fig. 3. The input impedance of a typical operational-amplifier appears as a resistance from the input pin to ground and is usually a high value of resistance.

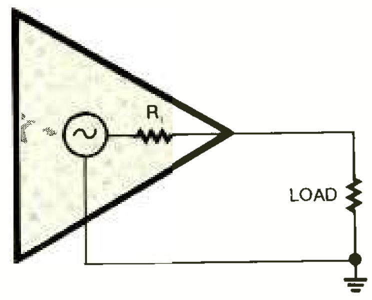


Fig. 4. The output impedance of an operational-amplifier appears as a low-value resistance in series with a voltage source. Heavier load demands cause more voltage to be dropped across this internal resistance, causing less voltage to be available for the load.

agree. As long as the output current remains below that 25-milliamp figure and the op-amp is designed into a closed-loop, the output impedance remains very low. The 741 will protect itself from thermal annihilation by limiting the output current.

STRike Out?

Q *I am looking for the datasheet and some background information for the STR2005 and STR2012. Can you help me please? I am giving up with the Internet.—H.D., via e-mail*

A Don't give up on the Internet. Although I find it far easier to research "common" semiconductors in my paper databooks, the Internet does offer some sites that help with manufacturers for which you have no books or oddball chips that aren't covered by the books you do have. ChipDocs has a listing for datasheets in .pdf form for both of those Sanken switching-regulator integrated circuits. At their *www.chipdocs.com* Web site, enter your chip type number in the search block at the left of the screen. I'm not sure what you're looking for in the area of "background" information, but Sanken's Web site is *www.sanken-ele.co.jp*. They have a U.S. office at Box 15036, Worcester, MA 01615; 508-853-5000.

ICs On Social Security

Q *Do you know anyplace that stocks obsolete ICs and sells them in small quantities? I need an LM391N. I would buy 2 or 3, but don't need any more than that.—B.S., via e-mail*

A The only place that I'm aware of is Summit Electronics, and they appear to have a few different lots of those. However, I don't know if they'll sell "onesies" and "twosies." You'll have to ask. Their Internet site is *www.summitelectronics.com*. If any readers have sources for obsolete semiconductors, whether diodes, transistors or ICs, drop me a line or e-mail. I love to keep notes on things like that. By the way, that chip had been available at one time as a substitute only through the SK line as SK9317.

Yashica Camera Chip

Q *You are my last hope. I have a Yashica MG1 35-mm camera, and it is in need of a replacement IC chip for the auto exposure to work. The chip is marked M5126L and has eight in-line pins. It seems to be made by Mitsubishi, since it has a symbol containing three diamonds. No reference guide lists it; and Yashica doesn't have any replacement parts for this camera, since it is nearly 30 years old.—A.B., via e-mail*

A I'm not sure if it's worse to have a chip in the lens or not have that chip in the camera body. A 30-year-old camera is a tough one to find support for unless it's a Nikon, Hasselblad, Leica, or some other premium brand. I came up with zilch everywhere I tried. More than likely this was a short-run, custom-chip run; and your only source for a replacement may only be in another MG1 that was recovered after falling 30,000 feet from a Boeing into a lagoon. I don't want to be your last hope, so check E-bay for some of those. Maybe Mitsubishi has a lead for you. Contact them at Mitsubishi Electrical and Electronics USA, Electronic Device Group, 1050 East Arques Avenue, Sunnyvale CA 94085. Their phone number is 408-730-5900.

Writing to Q&A

As always, we welcome your questions. Please be sure to include:

(1) plenty of background material,

(2) your full name and address on the letter (not just the envelope),

(3) and a complete diagram, if asking about a circuit; and

(4) type your letter or write neatly.

Send questions to Q&A, **Poptronics**, 275-G Marcus Blvd., Hauppauge, NY 11788 or to *q&a@gernsback.com*, but do not expect an immediate reply in these pages (because of our backlog). We regret that we cannot give personal replies. Please no graphics files larger than 100K.

JOHN IOVINE

UFO Detector, Part 2

We will now continue with the subject of building a UFO detector, which was begun in the January issue.

Circuit Construction

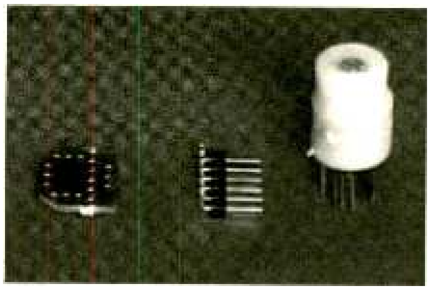
The UFO Detector schematic is shown in Fig. 1. If you already purchased the UFO Detector kit, it included two printed circuit boards (PCBs). The smaller of the two PCBs is for mounting the digital compass sensor. The larger PCB is the main circuit board. The sensor PC board attaches to the main board through either a 6-pin right-angle connector (vertical model) or 6 three-inch lengths of 22 gauge stranded wire (horizontal model). While the PCBs simplify construction, there is nothing critical about the circuit. If you prefer not to purchase the kit, the circuit may be constructed on a standard prototyping board. Do keep in mind that whatever model you decide to build, the compass sensor itself must be held upright (with respect to gravity) and cannot vary greater than 12 degrees without degrading its performance.

Main PCB

The topside of the main PCB board has a white silk screen depicting the parts placement. Figure 2 shows parts placement, as well as the speaker, LED, tilt switch, and battery clip connections. Mount the components to the topside of the board. Solder the components from the bottom side of the board and clip away any excess wire.

Mounting The Sensor

The mounting of the digital compass sensor requires special mention. In the UFO Detector kit, the small PCB is for mounting the digital compass. The spacing between the leads of the digital compass sensor is small. This spacing makes the compass difficult to mount



Here we see the sensor components, PCB and digital compass right-angle connector for the vertical model. All of these parts fit together and mount into the housing of your choice.

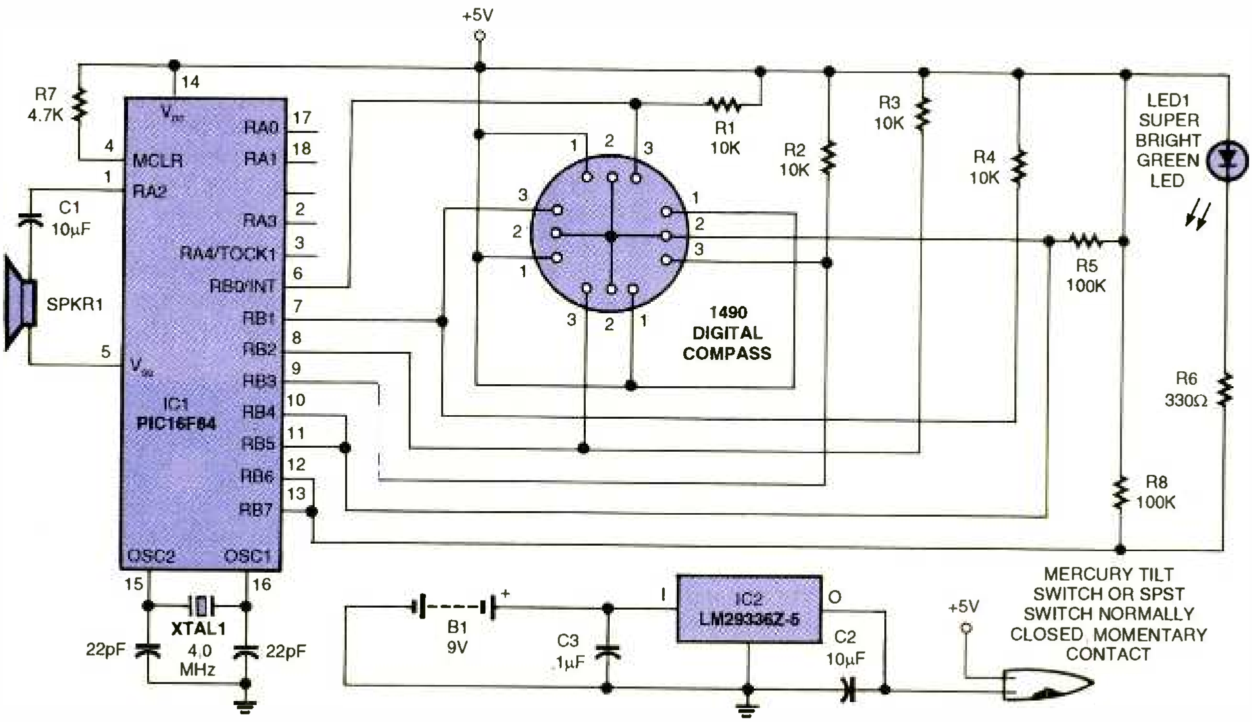


Fig. 1. Here is the schematic for the UFO Detector. A PIC chip serves as the main microcontroller and a digital compass is used to detect magnetic anomalies.

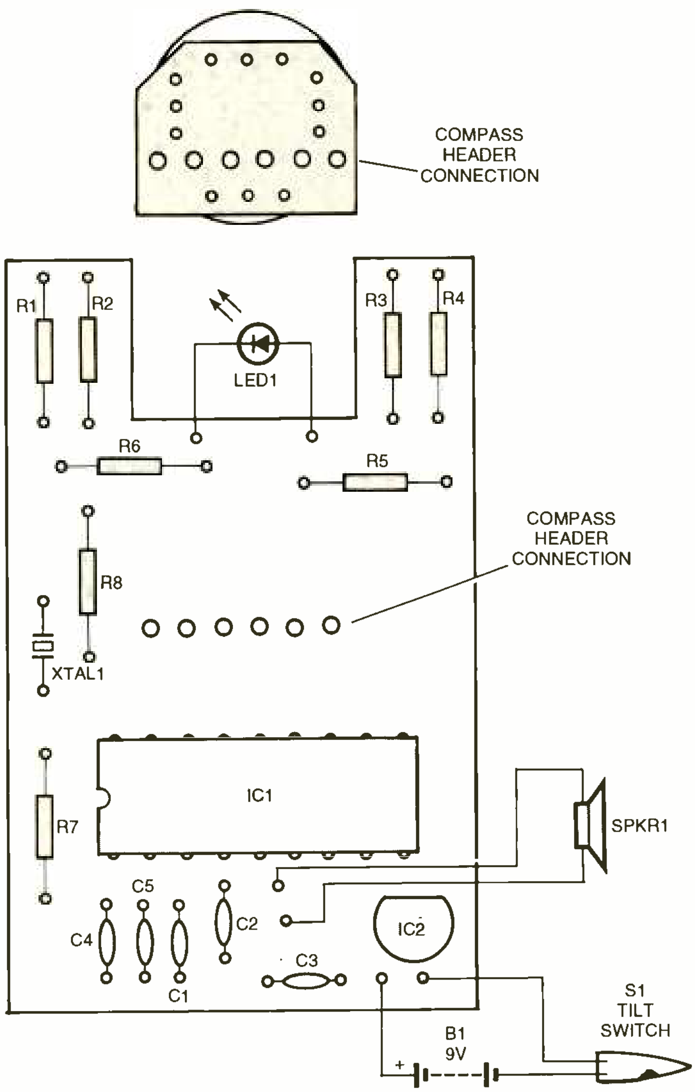


Fig. 2. This diagram shows the parts placement on the PCB. The entire unit is compact and can fit into a variety of cases.

and solder to its PCB. Before you start to mount the digital compass to its PCB, first check that the PCB is orientated correctly (right side up). On the topside of the PCB is the letter "T" and on the bottom side the letter "B." Mount the digital compass on the "T" topside and solder the leads on the "B" bottom side. Check this first—you don't want to spend the time getting everything mounted and soldered only to discover that the sensors are on the bottom side.

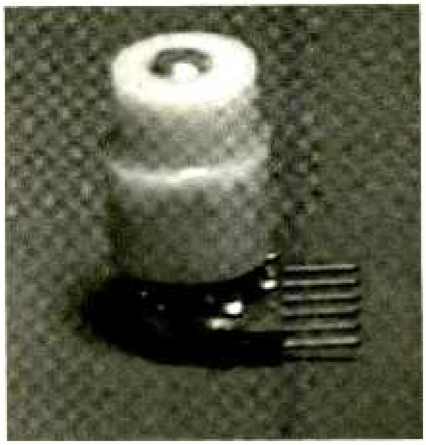
After you have mounted and soldered the sensor to the PCB, you're not quite out the woods yet. If you are constructing the vertical kit, a 6-pin right angle header connector is provided. Mount the header to the sensor PCB through the bottom and solder it on from the bottom. Now mount the sensor to the main PCB by soldering the other side of the 6-pin right angle header to the main PCB.

If you plan to mount the sensor horizontally, connect the PCB to the circuit board using six 3- to 4-inch-long lengths of 22 gauge stranded wire. Keep the orientation of the PCB boards, using the stranded wires, the same as it would be using the 6-pin header. The flexible 22 gauge stranded wire allows you to bend the wires backwards and secure the sensor in a horizontal plane with respect to the main PCB.

Continue to mount and solder the components to the main printed circuit board—the LED, speaker, and 9-volt battery clip—with about 6-inch leads of wire. The lead length may be adjusted according to whatever housing you have decided upon.

Reset Switch

The reset switch in this circuit interrupts the main power going to the cir-

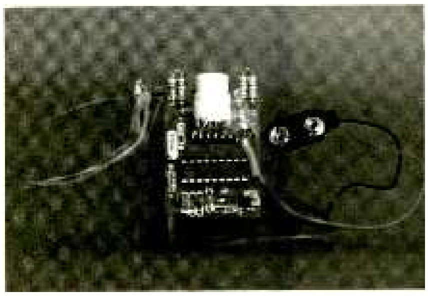


The vertical sensor model is finished and ready for mounting. The entire unit receives its supply power from a standard 9-volt battery.

cuit. For a reset switch you may use any style of momentary-contact, normally closed switch you like. The kit includes a small mercury-tilt switch that is glued to the PCB in the same orientation (vertical or horizontal) as the sensor. The tilt switch is wired into one of the main power leads. The mercury switch eliminates mounting a momentary contact pushbutton switch in the UFO Detector housing. You reset the circuit by turning it over for a few seconds and then bringing it right side up.

Testing

Choose a location that is relatively clear of external magnetic fields and large ferrous objects, which could cause false triggering or reduced sensitivity, respectively. Install a fresh 9-volt lithium battery to apply power to the circuit. After seven seconds, the UFO Detector circuit will beep and flash its LED announcing it's in detector mode. Once in its detector state, the UFO Detector will signal any magnetic or electromagnetic anomalies and any change it senses in Earth's magnetic field.



This is the UFO Detector circuit for the vertical model. Notice that the sensor is aligned to the top of the board and the LED is mounted off of the PCB.

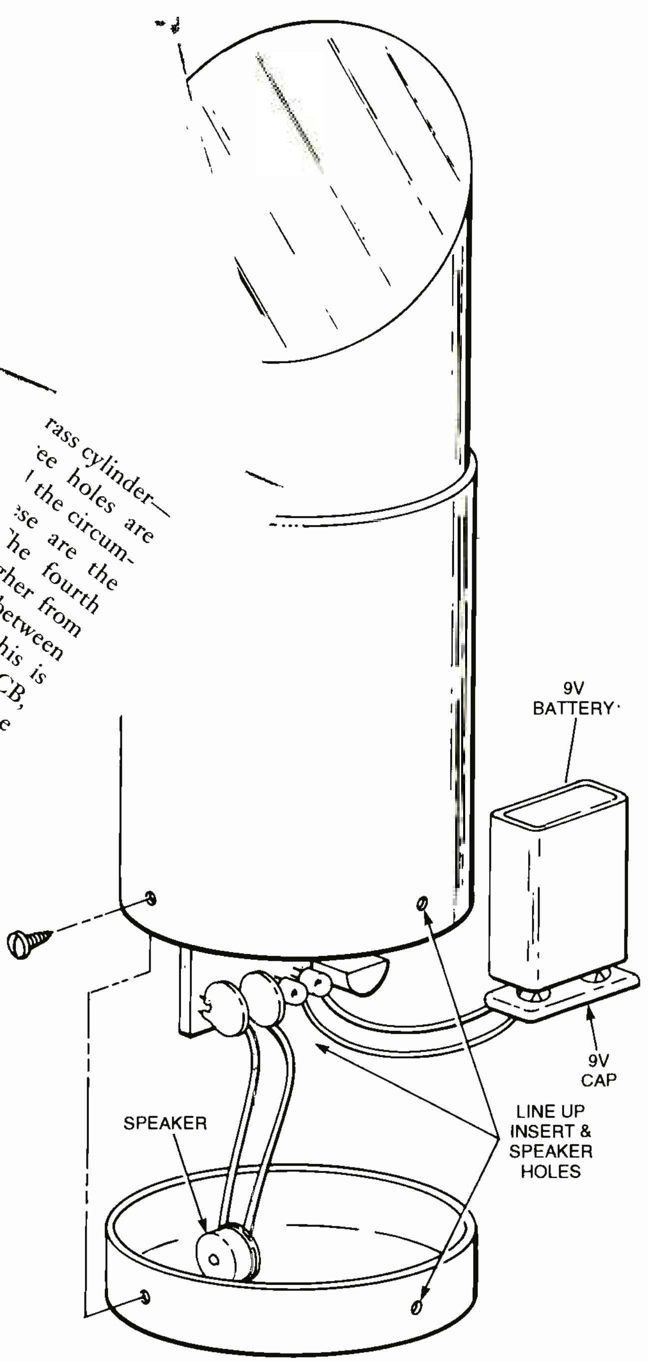


Fig. 3. This exploded-view diagram shows how the UFO Detector is mounted snugly within the housing, which includes a brass cylinder, green acrylic top, and internal base.

There are many ways to test the UFO detector. One of the easiest is simply to rotate the circuit 90 degrees. The UFO Detector cannot tell that it's been moved, sees its movement (rotation) as a change in the Earth's ambient magnetic field, and starts signaling (flashing the super bright LED and beeping). Once triggered, the UFO Detector will continue to signal by flashing its LED and beeping until it is reset. If you used the mercury-reset switch, reset the circuit by turning the circuit upside down for a few seconds and then placing it right side up.

Another way to test the UFO Detector is by waving a magnet an inch or so away from the detector's sensor. If one rushes a magnet past the detector very quickly, it may not trigger the detector. The reason is that the sensor dampens quick movements and the microcontroller may ignore events that occur within a two-second time period. A good UFO event will need to last longer than two seconds to be captured.

This is the horizontal model of the UFO Detector circuit. Comparing this photo with the vertical model, we see the sensor with a central location rather than aligned with the end of the board..

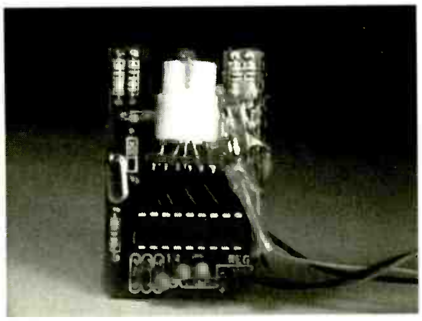
In addition to passing a magnet by the detector, one can obtain similar results by waving a ferrous material (like iron) close to the detector sensor in the same way.

Other possible terrestrial triggers include external electromagnetic fields, as discussed previously.

Finishing The UFO Detector

Once the circuit has been tested, it can be mounted inside a suitable housing. The unit should operate over six months on one 9-volt lithium battery. However, when the detector is sounding an alarm and beeping and flashing the LED, its current consumption increases

Used for the desktop model of the UFO Detector circuit, this brass and plastic case can be ordered from the author or a custom case can be built.



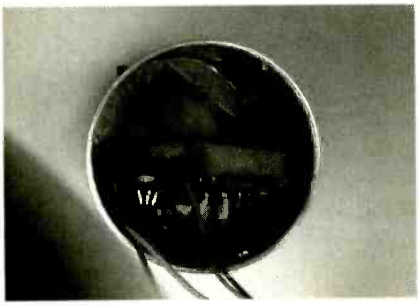
In this photo of the vertical model of the UFO Detector circuit, note that the LED is attached directly to PCB. The top of the LED should be positioned in the PCB cut-out in such a way that the LED does not rise above the PCB.

300 times. So the longer the alarm mode is active, the shorter the overall battery life will become. Check the UFO Detector function every week or so when you first build it just to make sure it's working. Testing the detector for a few seconds each week will not have much impact on the battery life. I'm sure after a month or so that you will be confident enough in the unit, and it will not be necessary to check its functionality.

Finding Housing

If you are at a loss for a UFO Detector housing, you can purchase a desktop housing that resembles an oversized lipstick case containing green iridescent lipstick. This housing includes the brass cylinder, green acrylic top, and internal base (not seen).

It's important to realize that this case requires the vertical UFO Detector. When building the vertical model for this enclosure, mount the LED directly to the main PCB board. The top of the LED should be positioned in the PCB cut-out in such a way that the LED does not rise above the PCB (see Fig. 8). After the circuit is assembled and tested, attach a small piece of ⅛-inch thick conductive foam



This photo shows the entire circuit mounted inside the brass and plastic "lipstick" case. Some protective foam has been mounted on the PCB's solder-side.

PARTS LIST FOR THE UFO DETECTOR

SEMICONDUCTORS

IC1—PIC16F84, pre-programmed microcontroller
IC2—5-volt voltage regulator
LED1—Green, super-bright LED

RESISTORS

(All resistors are ¼-watt, 5% units.)
R1–R4—10,000-ohm,
R5, R8—100,000-ohm
R6—330-ohm
R7—4.7K-ohm

CAPACITORS

C1, C2—10-µF capacitor, 12 volts
C3—.1-µF capacitor, 12 volts

ADDITIONAL PARTS AND MATERIALS

Dinsmore 1490 Digital Compass
X1—4.0-MHz crystal
(2)—22-pF capacitors, 12 volts (for crystal)
9-volt battery clip; mercury tilt switch; miniature speaker (approx 1-inch diameter, 8 ohms); desktop housing; 9-volt lithium battery.

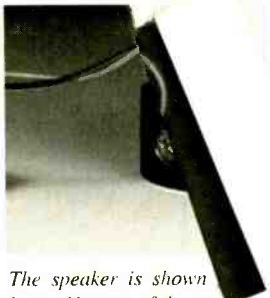
NOTE: UFO Detector Kit containing two printed circuit boards, and all the components listed above, ($ 39.95) can be ordered from Images SI, Inc, 39 Seneca Loop, Staten Island, NY 10314; 718-698-8305; *www.imagesco.com.*

The following components are sold separately from the same supplier: Dinsmore 1490 Digital Compass, $14.95; PIC16F84 pre-programmed microcontroller, $8.95; 9-volt lithium battery, $8; Area 51 UFO Model (separate delivery charge), $25; Desktop Housing Kit includes polished and lacquered brass cylinder, wood base, and green plastic wand, $20.

to the back of the PCB. It acts like a battery cushion once the PCB is mounted in the housing.

Final Assembly

Mount the completed UFO Detector circuit inside the brass cylinder using an off-the-shelf silicone sealant. To align the UFO Detector circuit properly in the cylinder, first



The speaker is shown ... base. No part of the spe... side the cut-out, as the bas... cylinder properly.

look at the base of the b... it has four holes. Th... spaced equidistant aroun... ference of the base—th... screw-mounting holes. ... hole is positioned a little hi... the bottom and is centered... two of the equidistant holes... the speaker hole. To mount th... place a small amount of silicone inside of the cylinder on the op... side from the speaker hole. G... push the UFO Detector circuit ... the silicone, component side in (fac... the cylinder wall); the LED should ... pointed toward the top of the cylinde... Push the detector up until it touches the top of the cylinder case. The opposite side of the cylinder is the space where the 9-volt battery will be held. You may wish to insert a battery in this space while the silicone sets to insure there will be sufficient space.

After the silicone has set (this usually takes about 24 hours), it's time to work on the base. The base has a hole cut out for the speaker. The speaker from the PCB is glued into the base's cut-out and allowed to dry. No part of the speaker should extend outside the cut-out, as the base will not slip into the cylinder properly.

To finish the assembly, place the battery in the case bottom side up, so that the 9-volt battery clip is facing down. Line up the three screw holes on the bottom piece with the three holes on the case, making sure the speaker is also aligned with its speaker hole. Then slide the bottom piece in. Carefully screw the three 4/40 brass screws into the base.

Once the battery is installed, keep the unit upside down to prevent the UFO Detector from triggering until you are ready to set it down in its location. Place the green, fluorescent wand in the base. Rotate the wand to your liking. (See the "Testing" section.)

Now your UFO Detector is ready to go to work looking for "contact." ■

mailto: serviceclinic@gernsback.com

SAM GOLDWASSER

THE BASICS OF SMPS TROUBLESHOOTING

Disclaimer

Careless troubleshooting of a line-powered switchmode power supply can result in severe electrical shock or electrocution. This is potentially more lethal than the high-voltage section of a TV or monitor due to the availability of high current. Even the charge on the main filter capacitors with the unit unplugged can kill. This warning includes those innocent-looking laptop and Zip-drive power packs as well.

Neither the author or publisher will be responsible for damage to equipment, your ego, countywide power outages, spontaneously generated mini (or larger) black holes, planetary disruptions, or personal injury or worse that may result from the use of this material.

Safety

Most *s*witch*m*ode *p*ower *s*upplies (SMPS) are directly line-connected (often called "off-line switchers"). The major safety hazard in power supplies comes from these line-connected components—especially the large, potentially lethal, electrolytic capacitors with 320 V or greater DC when powered, as well as for some time after being unplugged. Be aware that the danger could persist, especially if the power supply is not working correctly (even though the supply does not blow fuses, since there may be minimal current flowing.) For additional safety information, see my Web site *www.repairfaq.org* or previous "Service Clinics."

Tips on SMPS Troubleshooting

The diagnosis of problems in switchmode power supplies is sometimes complicated because of the interdependence of components that must function properly for any portion of the power supply to work. Depending on design, the SMPS may or may not be protected from overload conditions and may fail catastrophically under a heavy load even when supposedly short-circuit-proof. There is particular stress on the switching devices (they are often 800-volt transistors), which can lead to early or unexpected failure. Also, SMPSs may fail upon restoration of power after a blackout if there is any kind of power spike, since turn-on is a very stressful period—some designs take this into account and limit turn-on surge.

When you are testing these devices, a series light bulb to limit current, along with a variac, will be very useful. An ESR meter is an invaluable tool for quick checks of electrolytic capacitors—very common points of failure, especially in equipment like VCRs that are perpetually powered.

General SMPS Troubleshooting Approach

The following guidelines are useful for attacking SMPS problems.

- Determine that it is not something trivial like a blown fuse due to a legitimate overload (that has since been removed).

- Categorize the problem into: startup problem, catastrophic failure, incorrect outputs, or excessive ripple or noise.

- Determine what the proper output voltages should be. Identify the main (regulated) output.

- Disconnect the supply from the equipment it is powering, if possible. This precaution will prevent the possibility of expensive damage should the output voltages soar to stratospheric levels for some reason. If this is not possible, you will need to be extra careful—always use a variac to bring up the input slowly and monitor the main output at all times.

NOTE: Some SMPS designs require power to be applied instantly to provide the start-up voltage to the controller. If this is the case with yours, it won't be possible to bring up the voltage slowly (unless you power that chip separately. So, if nothing happens when doing this, don't panic—it may be a feature, not a bug). It should still be possible to run the unit at somewhat reduced line voltage on the variac.

CAUTION: Running any SMPS at greatly reduced line voltage will be stressful for it, especially if the output load is a significant fraction of its full load ratings. In addition, at some range of line voltage, the output regulation may not work properly and the output(s) may go much higher than expected. Use dummy loads in place of the valuable equipment, if possible, when doing such testing!

Determine an appropriate load for the outputs (if not connected to the equipment). A typical SMPS will need a minimum of 5% to 20% of full load current at least on the main output to regulate properly. Others may not need any load—it depends on the design or whether or not they may have an internal load.

Here are some typical load currents:

- VCR—0.2 A on +5 V and +12 V outputs.

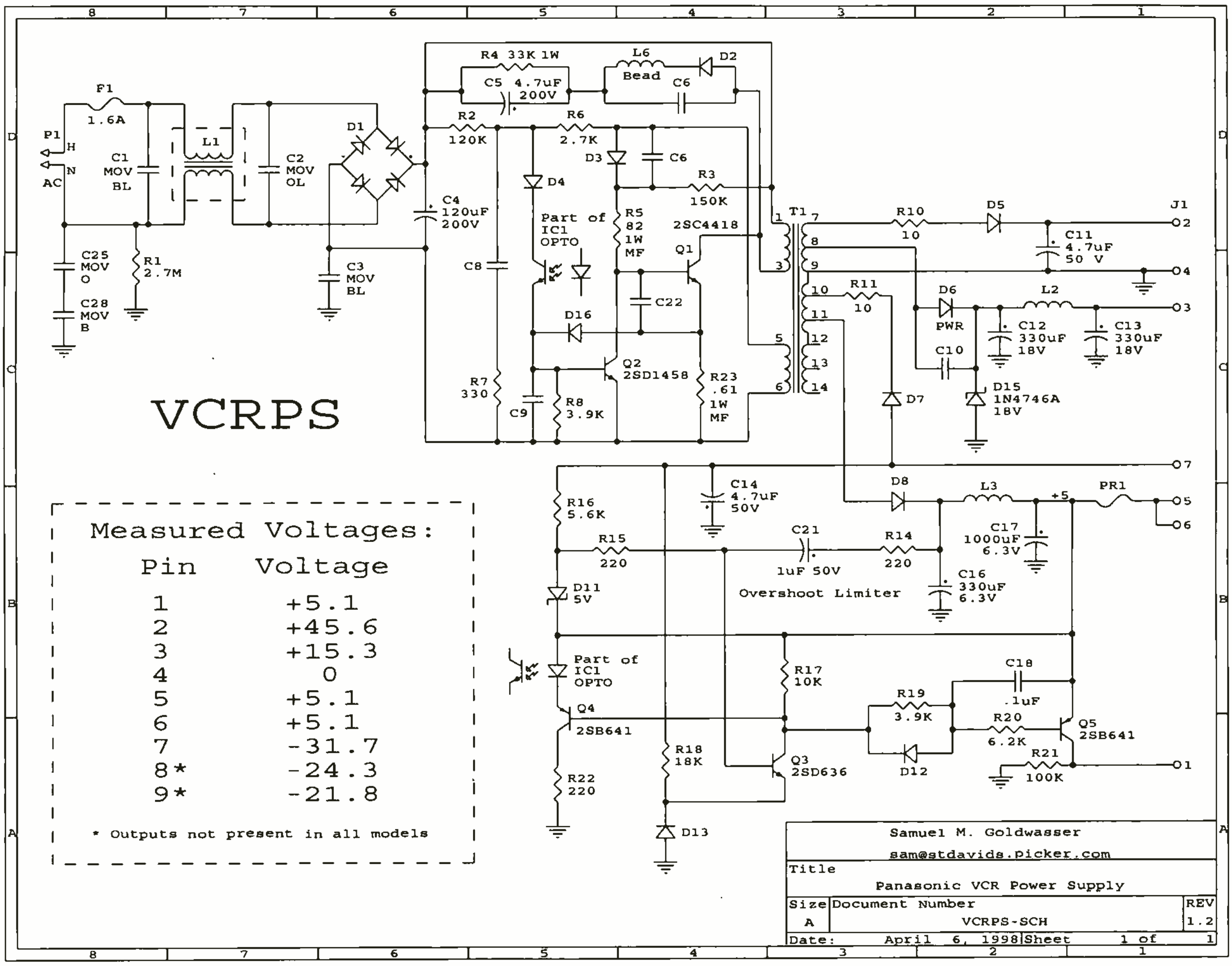


Fig. 1. This is the schematic of a common VCR power supply. The same power-supply design is used with minor variations in a wide variety of Panasonic (and clone) VCRs from the 1980s and 1990s (and may continue to this day). Depending on the specific model, there may be slightly different output voltages and number of outputs, but the general organization is identical.

- PC—2 A on +5 V, 1 A on +12 V.
- Monitor—0.2 A on +60 to +120 V output.
- Typical 40 W switcher —1 A on +5 V and +12 V.

Troubleshooting Procedure

Since there are usually several fault conditions that can result in an aborted start-up or cycling behavior, the basic troubleshooting procedure needs to be modified when dealing with SMPSs using controller ICs like the UC3840 or UC3842; but most of the techniques are similar.

Start-Up Problems. Check the power on the switchmode transistor and work back from there if there is none. Check for open fusable resistors in the return as well. Check for power to the controller. Determine that no fault-condition inputs have abnormal voltages during startup. Check for drive out of the controller IC and see if it reaches the switchmode transistor. You will probably need to power cycle the line input and monitor each of the relevant signals as you do so. Determine whether the supply is shutting down abnormally due to a legitimate or bogus over-current or over-voltage condition, or if it's never actually starting up due to a lack of a voltage or a stuck-at fault on a sense line. Monitor its power to determine if it is stable during start-up—a bad capacitor or diode could result in insufficient or decreasing voltage that causes the controller to give up.

Powering the controller separately may help in troubleshooting these and related problems. This will decouple the chopper drive from the voltage usually derived via a winding on the high-frequency transformer to power the controller once the supply is running.

Blows Fuses. Check primary-side components, switchmode transistor(s), and all other semiconductors for shorts. Then check for open fusable resistors and bad connections. There is a chance that a blown transistor took out the controller chip as well. Under normal conditions, controllers like the UC3840 or UC3842 should limit current on a PWM cycle-by-cycle basis. Therefore, a blown fuse indicates a failure of either the switchmode transistor, controller, or both. However, designs with discrete components may do almost anything.

Power Cycling. Start by making sure you are providing the minimum load if one is required. Many SMPSs will cycle on over-voltage if there is none. Some may blow up! Assuming the load conditions are normal, monitor current and voltage sensing, as well as V_{CC} inputs to controller to determine if any are at fault. Open or out-of-tolerance resistors may result in incorrect sensing. Check for faulty reference-setting components

TABLE 1

Common Failure Modes

Problem	Symptoms	Diagnosis
Faulty primary-side components —rectifier diodes, filter capacitor(s), MOVs, and other parts located before the switch-mode (chopper) transistor(s) may short due to a surge, lightning, or for no apparent reason.	Totally dead supply—fuse blows instantly (vaporizes or explodes) even if switchmode transistor is removed unless a fusable resistor has blown to protect the fuse.	Test all components on line side of high-frequency transformer for short-circuit failures with a multimeter.
Shorted switchmode transistor—may take out additional parts such as fusable, flameproof resistors in collector or emitter circuits (or source or drain circuits for MOSFETs).	Totally dead supply—fuse blows instantly (vaporizes or explodes) unless fusable resistor has opened.	Measuring across C–E or D–S of switchmode transistor yields near zero ohms even when it is removed from circuit.
Shorted rectifier diodes in secondary circuits —these are high-frequency, high-efficiency diodes under a fair amount of stress.	In a very basic supply without over-current protection, the failure of one or more of these diodes may then overload the supply and cause a catastrophic failure of the switchmode power transistor (see above) and related components. Thus, these should be checked before reapplying power to a supply that had a shorted switch-mode transistor. On short-circuit protected supplies, the symptom may be a periodic "tweet-tweet-tweet" or "flub-flub-flub" as the supply attempts to restart and then shuts down. Any power or indicator lights may be blinking at this rate as well.	Test with an ohmmeter—a low reading in both directions indicates a bad diode. Sometimes these will test fine but fail under load or at operating voltage (easiest to replace with known good diodes to verify diagnosis). Rectifiers either look like 1N400X type on steroids—cylinders about 1/4-inch × 1/2-inch (example: HFR854) or TO220 packages (example: C92M) with dual diodes connected at the cathode for positive supplies or the anode for negative supplies (the package may include a little diagram as well). These may either be used with a center-tapped transformer or simply parallel for high current capacity. If in doubt, remove from the circuit and test with the ohmmeter again. If it's not the output used for regulation feedback, try the supply with the rectifier removed.
Bad start-up circuit—initial base (gate) drive is often provided by a high-value, high-power resistor or resistors from the rectified AC voltage. These can simply open for no good reason	In this case, the supply will appear totally dead, but all the semiconductors will check out and no fuses will blow.	Check the startup resistors with an ohmmeter—these are the power resistors in the AC line input section. WARNING: There will be full voltage on the main filter capacitor(s): 1× or 2× peak or around 160 or 320 V_{DC} depending on design. Discharge before probing.
Dried-up capacitors—either input or output side.	The main filter capacitor may dry up or open and cause the output to be pulsing at 60 (50) or 120 (100) Hz, causing all kinds of regulation problems. Excess ripple under moderate load is an indication of a dried-up or open capacitor. In extreme cases, a main filter capacitor with greatly reduced capacity or one that is totally open may result in failure of the switchmode transistor and a dead supply that blows fuses or fusable resistors.	Measure voltage across main filter capacitor(s). If the reading is low and drops to a much lower value to 0 instantly upon pulling the plug, then one of these capacitors may be open or dried up. If you have an oscilloscope, monitor for ripple (use an isolation transformer!!). It is always a good idea to test the electrolytic capacitors whenever repairing a SMPS that has blown its switchmode transistor. Capacitors in the low-voltage section may fail causing regulation problems. Sometimes there are slew-rate limiting capacitors that feed from the primary output to the regulator controller to limit initial in-rush and overshoot. A failure of one of these may mess up regulation at the very least. For example, excess

(Table continued on page 52)

(Table continued from page 51)

		leakage may reduce the output of the main output (and, as a consequence, all the others as well). Where a controller like a UC3842 is used, a failure of the capacitor on its V_{cc} pin may result in a aborted startup or cycling behavior as it is starved for juice each time it pulses the switch-mode power transistor. In almost all cases, when in doubt, parallel a known-good capacitor of similar capacitance and at least equal voltage rating (except for these slew-rate limiting capacitors where substitution is the only sure test).
Bad connection/cold solder joints—as with all other mass-produced power systems (including TVs and monitors), cracked or defective solder connections are very common especially around the pins of high-power components like transformers, power resistors and transistors, and connectors.	Almost any kind of behavior is possible. The unit may be erratic, intermittent, or totally dead.	Visually inspect the solder side of the circuit board using a bright light and magnifying glass, if necessary. Gently prod or twist the circuit board with an insulating stick to see if the problem can be made to change. Note that a one-time intermittent can blow many components, so inspecting for intermittents is a really good idea even if you believe that all bad components have been replaced.
Regulation problems—outputs high or low.	Voltage has changed and adjustment pot, if one exists, has no effect or is unable to set voltage to proper value.	Most common parts are readily available from parts distributors like MCM Electronics, as well as general electronics distributors like DigiKey and Mouser. Rebuild kits are available for many common supplies used in VCRs, monitors, and terminals. Also, while it is tempting to suspect any ICs or hybrid controllers—and especially the high frequency transformer—since it is thought that replacements are difficult and expensive to obtain, these parts are pretty robust and don't make the top 10 list.

like zener diodes. With the series light bulb and/or variac, disable each of the sense inputs by bypassing the appropriate components. If one of these experiments prevents the cycling behavior, either that circuit has a faulty component or the controller IC's input characteristics have changed and it will need to be replaced.

Regulation or Ripple/Noise Problems. Check main HV filter capacitor and other filter capacitors for decreased value or opens. Check regulation feedback components to controller, including any reference voltage output and zener diodes. Determine if the controller is responding to error voltage.

Initial Post-Repair Testing

Once defective parts have been replaced, if possible, remove the normal load from the supply, in case it decides to put excessive voltage on its outputs. Replace with a dummy load. For a multiple-output supply, the most important output to have a load on is the one that is used for regulation. However, some modest load on all the outputs is preferred. You should be able to determine a suitable value by considering the application. For something like a VCR, a few hundred mA on the main output is probably enough. This load would require something like a 25-ohm, 2-watt resistor for a 5- or 6-volt output or 50-ohm, 5-watt resistor for a 12-volt output (depending on which is the primary output).

For a PC power supply, a couple of amps may be needed—a 2- or 3-ohm, 15-watt resistor on the +5 output. The minimum load is sometimes indicated on the specification sticker. In the case of a TV or monitor, disconnecting the load may not be possible (or at least, not easy).

If available, use a variac to bring up the input voltage slowly while observing the main output. You should see something at about 50% of normal input voltage—50- or 60-volts for a normal 115 V_{AC} supply. With a small load, the output should very quickly reach or even exceed its normal value. Regulation at very low line voltage may be far off—this is often normal. Just make sure you're using dummy loads so your equipment can't be damaged.

If you do not have a variac, put a light bulb in series with the line (this is desirable in any case). Use a 100-watt bulb for a TV or PC; 40-watt for a typical VCR. The light bulb should limit the current to a non-destructive value long enough to determine whether everything is okay. It may not permit normal operation under full load, however. When power is first applied, the light bulb will flash briefly, but may just barely be glowing once the output has stabilized. If it is fairly bright continuously, there is likely to still be a problem in the supply.

Once you are finished, save your schematic and notes for the future. For example, different models of VCRs even from different manufacturers, use the same basic design, and maybe even the same supply.

Panasonic VCR SMPS

The same power-supply design is used with minor variations in a wide variety of Panasonic (and clone) VCRs from the 1980s and 1990s (and may continue to this day). Depending on the specific model, there may be slightly different output voltages and number of outputs, but the general organization is identical. (See Fig. 1.) These models use discrete components throughout with feedback from the primary output (5- to 5.2-volts, depending on the model). They use an opto-isolator to essentially short out the drive to the main-chopper transistor (Q1) when the output equals the desired voltage. The most common problems found with any of these supplies is dried-up electrolytic capacitors. Generally, the first to go will be C16 and C17 on the +5.1 V_{DC} line and/or C21 in the feedback path (actual part type and number may vary slightly with model).

Either the primary output will be somewhat low (4 to 4.5 V_{DC}) or the supply will have gone over-voltage and blown the protection zener (D15), resulting in a high-pitched whine as the chopper struggles to drive current into a short circuit (this usually doesn't damage any other parts if caught in a reasonably timely manner). If any capacitor-related problems are found, it is a good idea to replace all the electrolytics in the supply. Model-specific capacitor kits as well as total-rebuild kits are available from places like *www.iglou.com/studiosound* and *www.mcmelectronics.com.*

Wrapup

This and last month's "Service Clinic" have just touched upon the issues in troubleshooting switchmode power supplies. However, it should be clear that they are not mysterious black boxes to be simply replaced or junked, but can be repaired in most cases. There is much more information on my Web site, *www.repairfaq.org*. As always, I welcome feedback via e-mail on this and any other electronics and laser-related topics. ■

LETTERS

(continued from page 3)

Also, have someone try to build kits from the actual instructions in the magazine, before many of us waste our time in dead-end problems due to typos.

Finally, cease wasting paper and valuable space on articles such as "Radio Signals and the Great Pyramid" and "A Time-Travelers Time Line." If I want pseudo-science such as this, I can listen to Art Bell or read some other magazine.
ROD MASH
Port Ludlow, WA

and another reader asks

Is it possible to have SETI projects in your magazine—if there are any?
PAUL KLETT
Lady Lake, FL

As always, we try to incorporate the readers' requests and suggestion into the editorial content of this magazine. Unfortunately, we can't please all the people all the time. Here we have two fine examples of how diverse our audience truly is. Would a man who might champion causes such as ridding the planet of the current blight of psuedo-science support another man who wishes to seek out strange, new worlds? Overall, I think this publication is slowly reaching a compromise for its readers.—Editor

What Happened To PICBasics?

I've been buying your publication for quite a few years now, including **Electronics Now** and **Popular Electronics**. In the last few issues of **Poptronics**, you were doing articles about *PICBasic* standard and *PICBasic Pro* versions for programming the PIC microcontroller microprocessors. Why did you stop? I was looking forward to more issues.

I joined a *PICBasic* group on the Internet to learn to program the PIC chips—they have over 200 members, many of whom might buy the magazine if you included articles on the subject. There are other groups that number in the thousands that would love it, too.

There are books about the subject, but some are too advanced for the beginner, and your articles were perfect. This is electronics (microprocessors) and people want it, so why not include it in your articles as an ongoing event? Thanks.
JESSE MONTGOMERY
via e-mail

We cover PIC chips often. Now, as far as covering PIC on a regular basis, besides the PIC-intensive "Amazing Science," I don't see a "PIC Corner" in our future. Then again, we are always reviewing new writers for new columns, so perhaps you and your friends in virtual "PIC Town" can get together and write the column. We wouldn't mind sharing your ideas in print.—Editor

DIGITAL DOMAIN

(continued from page 18)

Talk About the Information Superhighway, I incorrectly predicted that by now we would likely have a seamless national or international matrix for the communication of interactive multimedia. In other words, according to my crystal-ball reading, the worlds of broadband Internet access, cable TV, and videophones should have merged by now.

Later, however, I did predict the collapse of the dot-com economy. One more quote, from Lao Tzu in the 6th century BC: "Those who have knowledge, don't predict. Those who predict, don't have knowledge."

Reid Goldsborough is a syndicated columnist and author of the book *Straight Talk About the Information Superhighway*. He can be reached at reidgold@netaxs.com or *http://members.home.net/reidgold.*

JOHN HAYS HAMMOND, JR.

(continued from page 40)

As for the allegations that John Hays Hammond, Jr. was quite the character, there may be some hint of truth. There is a blurb on a Web site that suggests he is buried with his cat, and the grave is protected by poison ivy. What was he afraid of? Ghosts?

Finally, despite the fact that he was responsible for countless, important developments in technology, he is also credited with some quirky, borderline-silly, inventions. These include a hypodermic meat-baster, a magnetic bottle-cap remover, and a failed cure for baldness. Everyone is entitled to some fun, right?

John Hays Hammond, Jr. contributed enormously to the science of remote control, radio communications, radar, and so much more. He propelled the U.S. military through crucial advances that enabled them to be a step ahead of the enemy. He also helped launch this country's success in the world of technology.

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CHARLES D. RAKES

Download These Circuits From www.electronicsworkbench.com/poptronics

Fun With Magnets And Motion

Hobbies are intended to be an enjoyable relief from our everyday routine. Hobbies are what we can turn to in order to escape the troubles of the world for a brief period of time and allow our mind to shift gears and relax. Personally, I find building a simple project that combines both electronic circuitry and simple mechanics a great method of placing such problems on the back burner. It's kind of like a mind vitamin that produces no bad side effects.

This month we're going to share three such construction projects that use very basic circuitry and easy-to-fabricate mechanics. If there is a student you know who's looking for a simple and fun Science Fair project to build, you might suggest one of these. In any case, build one or more of these electronic/mechanical motion projects and let your imagination improve and expand the original design. They are not offered as step-by-step construction projects, but as basic guides to follow in building your own version.

Pendulum Swings

Our first project is a solid-state, magnetic-driven, swinging pendulum. The pendulum is about two feet tall with a 4-inch swing when powered by a 9-volt source. A 12-volt power source increases the swing to over six inches. The pendulum may be built about any size you desire. Of course, a much larger version will require more input power and a different drive coil.

The pendulum's electronics is shown in Fig. 1. An infrared interrupter switch made up of Q1 and LED1 is the sensing device that monitors the movement and position of the pendulum. At rest (see Fig. 2), the pendulum's timing flag that sets on top, blocks the IR path between LED1 and Q1. A phototransistor, Q1 is turned off and its emitter's voltage is zero. Also, when at rest, the magnets at the bottom of the pendulum are directly

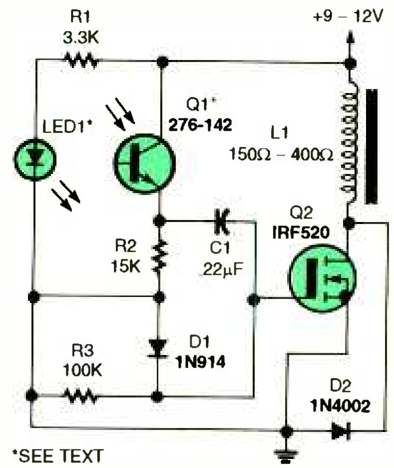

Fig. 1. The pendulum's electronics is shown in Fig. 1. An infrared interrupter switch made up of Q1 and LED1 is the sensing device that monitors the movement and position of the pendulum.

over the drive coil, L1. In addition, Q2, an IRF520 power HEXFET, is also turned off with its gate at ground potential; therefore, no current is flowing through the drive coil.

Moving the pendulum slightly in either direction—until the flag no longer blocks the IR light path—causes Q1 to turn on, raising the voltage at its emitter to near supply level. At the very instant that the IR light source is unblocked, C1 charges to near positive supply and sends a positive pulse to the gate of Q2. During the charge time, Q2 is turned on and supplies current to the drive coil, L1. The opposing magnetic field pushes the magnets attached to the bottom of the pendulum away from the coil. When the flag blocks the IR source on its swing back, C1 is rapidly discharged through D1 and R2. Then, as the flag moves on to unblock the source, C1 again charges positive. The cycle is repeated, sending the pendulum off in the opposite direction. Each time the pendulum passes the drive coil, it is repelled in that direction.

Just about any infrared interrupter

PARTS LIST FOR THE SOLID-STATE PENDULUM (FIG. 1)

SEMICONDUCTORS

LED1 and Q1—Mouser, part #512-H21A1; RadioShack, part #276-142
D1—1N914 silicon diode
D2—1N4002 silicon diode
Q2—IRF520 HEXFET, or similar

RESISTORS

(All resistors are ¼-watt, 5% units.)
R1—3300-ohm
R2—15,000-ohm
R3—100,000-ohm

ADDITIONAL PARTS AND MATERIALS

C1—0.22-µF, ceramic-disc capacitor
L1—150- to 400-ohm coil, (see text).

switch may be used, including the high-gain Darlington configuration; however, a suitable substitute may be constructed using an IR emitter diode and an IR phototransistor. RadioShack offers a matched infrared emitter and phototransistor pair (part number 276-142) for less than $2 that will work just fine.

The driver coil may be hand wound, or one can be salvaged from a relay. The physical size isn't too important, but the resistance should be somewhere between 150 and 400 ohms. A lower resistance coil will work, as well; however, it will draw more current and send the pendulum in a greater arc. A hand-wound coil would require several hundred turns of fine copper wire on a soft-iron core. Wire sizes from 30–36 enamel-covered copper will do; however, a coil from an old 120-volt relay will save time and make the construction job easier. No matter what drive coil is used, it must be connected in the circuit to repel the magnets on the pendulum. If the pendu-

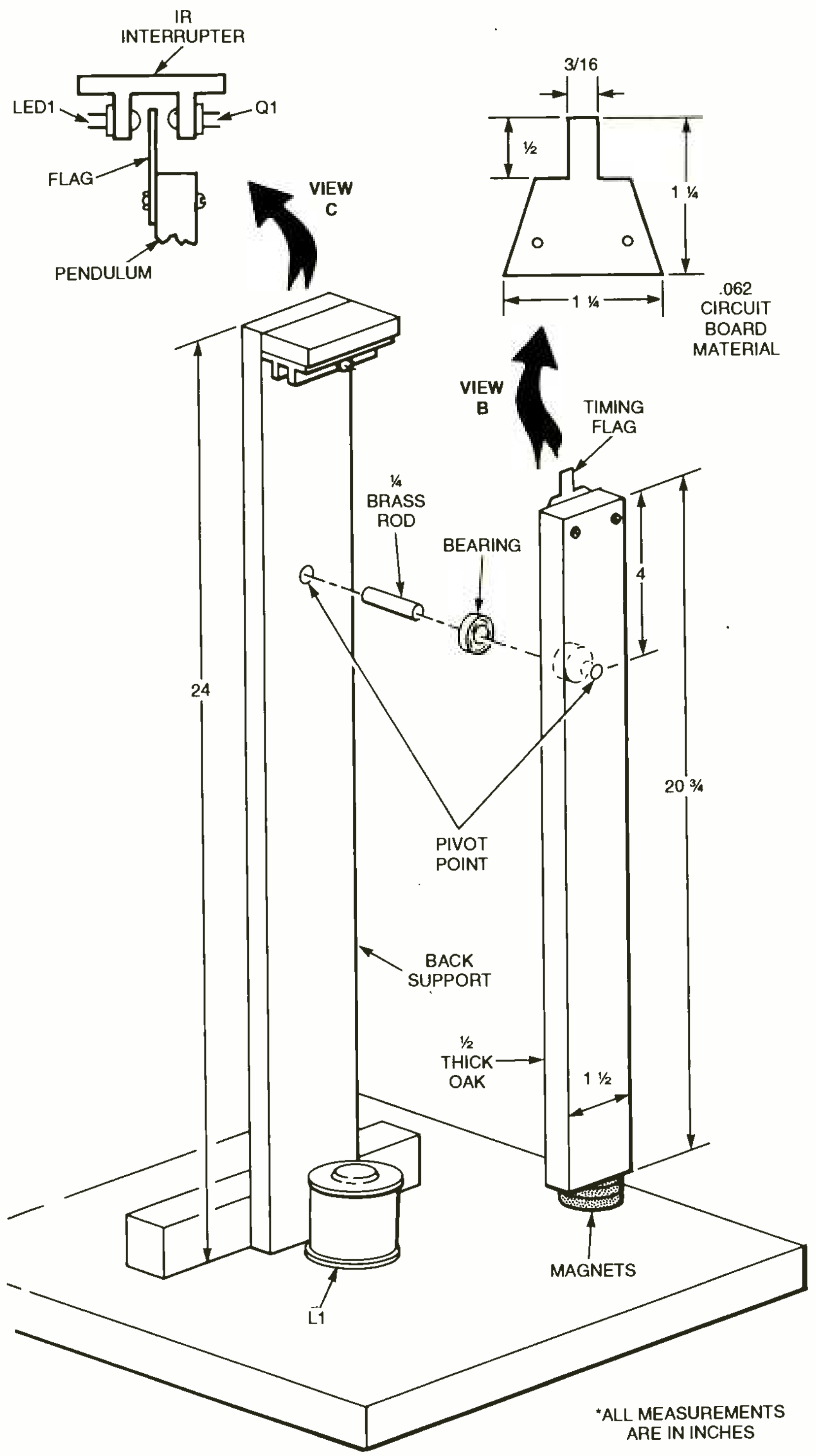

Fig. 2. The pendulum's mechanical construction can follow this drawing as a basic guide. Oak was used in our version, but just about any similar material will do.

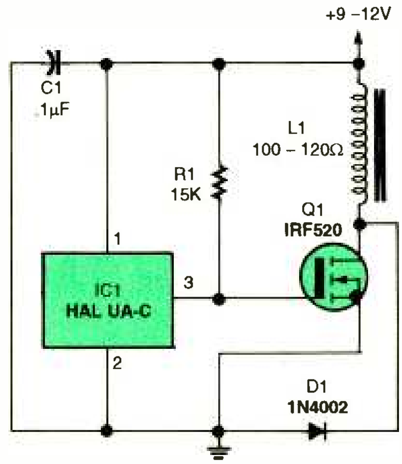

Fig. 3. The electronic circuitry, shown in Fig. 3, is as basic and simple as our previous project. In place of an IR-positioning sensor, like the one used in the pendulum, our wheel project uses a Hall-Effect device.

PARTS LIST FOR THE SOLID-STATE MAGNETIC-DRIVEN WHEEL (FIG. 3)

SEMICONDUCTORS

IC1—HAL 115UA-C Hall-Effect sensor, Digi-Key part #HAL 115UA-C-ND
Q1—IRF520 HEXFET or similar
D1—1N4002 silicon diode

ADDITIONAL PARTS AND MATERIALS

R1—15,000-ohm, ¼-watt, 5% resistor
C1—0.1-µF, ceramic-disc capacitor
L1—100–120-ohm coil, (see text).

lum is pulled back toward the coil, then the winding is connected to attract rather than repel the pendulum's magnets. Just reverse the connections on the driver coil, and the pendulum will be ready to swing.

The driver HEXFET may be any similar type, including an IRF510 that is available from RadioShack. If a lower resistance coil is used in a larger pendulum, a suitable heat sink should be added.

Mechanical Construction

The pendulum's mechanical construction can follow Fig. 2 as a basic guide. Oak was used in our version, but just about any similar material will do. The pendulum's pivot point is about ⅕th of the way down from the top. The pivot should be as friction-free as possible. In our version, a ball-bearing race was used with a brass support rod mounted to the back support board. The timing flag may be cut from any opaque material to the dimensions that are shown there. The width of the flag can vary some, but it should be close to these dimensions. If the flag is too wide, the magnetic push force will come too late after the pendulum passes over the driver coil. If too narrow, C1 will not have enough time to discharge before charging to send the pendulum on its way.

You can experiment with the component values of C1, and use R2 and R3 to fine-tune the timing of the drive pulse. In any case, take the time and build your own version of the swinging pendulum and let me know how it turns out. When time permits, I'm going to build a six-foot version.

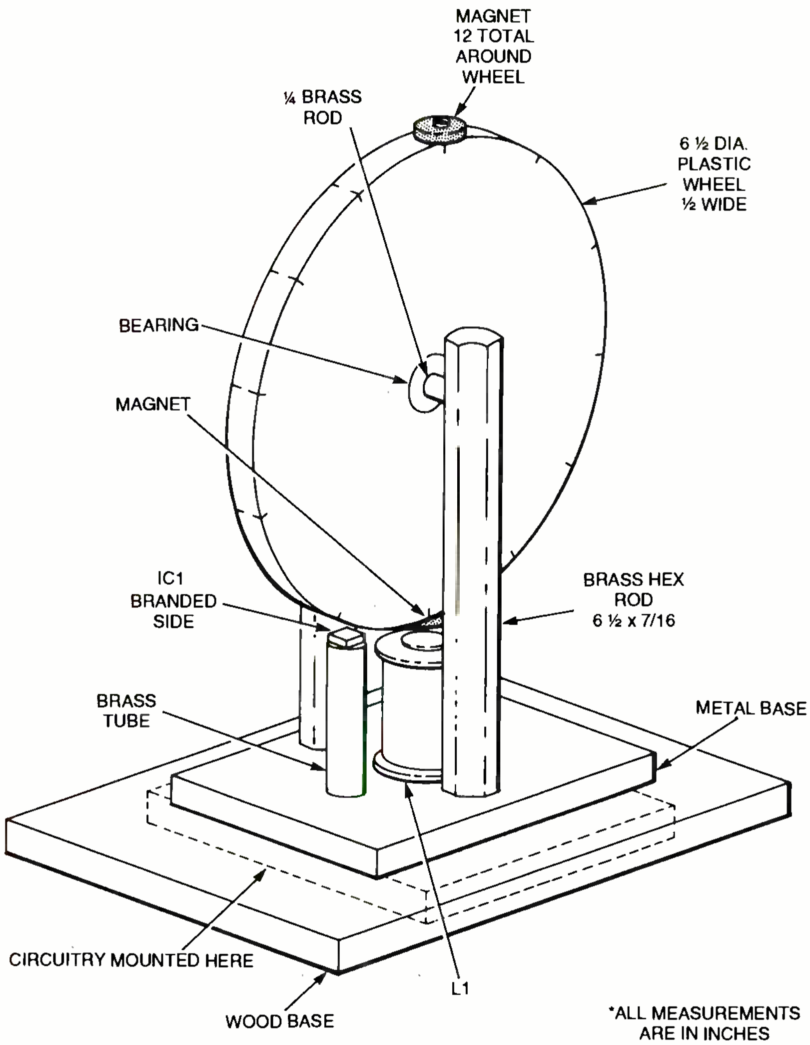

Fig. 4. A single 1-inch (OD) ball bearing with a ¼-inch opening (ID) was press-fit in the center of the wheel. Two brass hex rods, 6 ½-inches long by 7/16-inches wide, support the wheel.

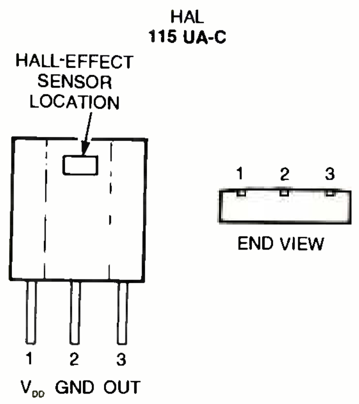

Fig. 5. Figure 5 shows two views of the HAL 115 UA-C IC that will make it easier to orient and mount in the supporting tube. Actually any non-magnetic material may be used to support the Hall-Effect device.

Around And Around We Go

Our next "escapist" project is a simple solid-state magnetic driven rotating wheel. The electronic circuitry, shown in Fig. 3, is as basic and simple as our previous project. In place of an IR-positioning sensor, like the one used in the pendulum, our wheel project uses a Hall-Effect device. The coil driver is the same type HEXFET, and the coil is similar but of a different shape and resistance. The main difference in the two driver coils is not a specific circuit requirement, but basically depended on what was on hand.

The wheel is a 6½-inch diameter by ½-inch wide plastic material that one time was part of another project; however, the type of material or diameter is not a critical requirement. Any non-magnetic material may be used for the wheel. Twelve 1⅛-inch diameter ceramic magnets are mounted in equal spacing around the edge of the wheel. Twelve holes are drilled around the outside edge of the wheel and tapped for 8-32 screws. The magnets are the type with holes in the center and are mounted with 8-32 screws around the wheel.

A single 1-inch (OD) ball bearing with a ¼-inch opening (ID) was press-fit in the center of the wheel, (see Fig. 4.) Two brass hex rods, 6½-inches long by 7/16-inches wide, support the wheel. The two rods are bolted to the base and are drilled to capture the ¼-inch round brass rod that passes through the bearing in the center of the wheel. Again, we used whatever materials were handy at the time, not specified requirements by any means. The fun in recreational building is to be creative—use your own ideas and materials. Be proud and be original.

The drive coil is mounted directly beneath the center of the wheel on the supporting base. The distance between the coil and magnets, as the wheel turns, should be about 1/16-inch. The Hall-Effect sensor is captured in the top of a brass tube mounted to the base about 1 inch from the center of L1 on the supporting base. The magnets should pass within ⅛-inch of the branded side of the Hall-Effect sensor. Don't mount the Hall-Effect assembly until the exact timing spot is found, which will require some experimenting and fine-tuning.

Figure 5 shows two views of the HAL 115 UA-C IC that will make it easier to orient and mount in the supporting tube. Actually any non-magnetic material may be used to support the Hall-Effect device.

A good starting location for the Hall-Effect sensor is shown in Fig. 6. The plan is to have the Hall-Effect sensor detect the oncoming magnet just as its edge passes over L1.

It's important that the North Pole of the magnets is mounted facing the outside of the wheel. The Hall-Effect sensor is sensitive to the North Pole. The circuitry is set up to repel each magnet as it passes by the driver coil. If the magnets are attracted rather than repelled, just reverse the leads to L1.

Here's how it works. Without a magnet near the Hall-Effect sensor, the output at pin 3 is low and the HEXFET is off, allowing no current to flow through L1. As a magnet moves into the sensing area of the Hall-Effect device, the output at pin 3 goes positive and turns on Q1 and powers L1. This magnetic field repels the magnet, pushing the wheel forward.

The 1N4002 diode's job is to protect the HEXFET from damage caused by the reverse voltage produced across L1 as it turns off.

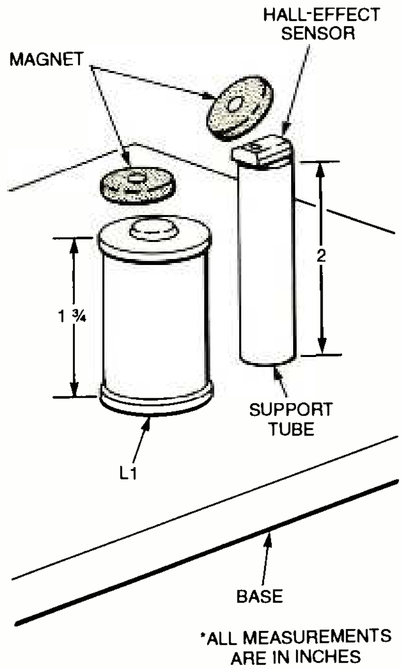

Fig. 6. A good starting location for the Hall-Effect sensor is shown above. The plan is to have the Hall-Effect sensor detect the oncoming magnet just as its edge passes over L1.

Making Changes

Both of our motion circuits can be modified extensively and still perform. The pendulum circuit could use a Hall-Effect sensor in place of the IR sensor. The circuit would require minimum changes; and a small magnet would be required at the top of the flag, with the Hall-Effect IC mounted above. The physical shape and size can follow just about any plan.

The rotating wheel can trade sensors by making some electrical and mechanical changes without complicating the project. The number of magnets used may be changed to more or less depending on the size of the wheel. Additional drive coils can be added by duplicating the original circuit and placing the new driver coil and sensor at another location around the wheel.

Your challenge is to build an improved version of one of our motion projects. If you accept the challenge and complete a project, please send the details to me here at **Poptronics.**

As usual, I've run out of space and time for this month's visit; however, stay tuned, and we'll continue next month with more electronic/mechanical projects. **P**

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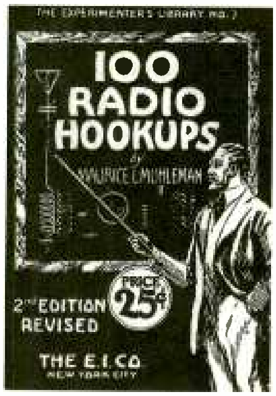

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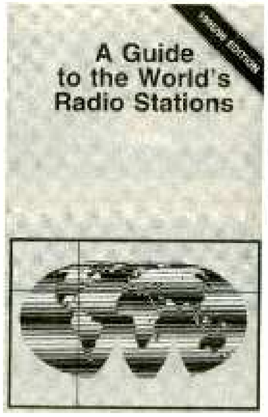

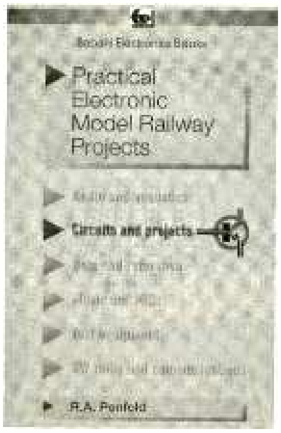

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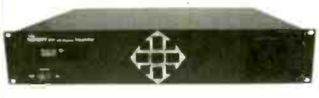

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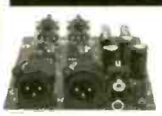

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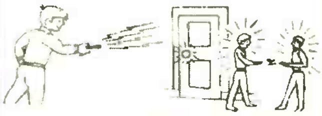

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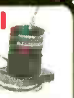

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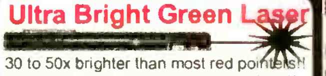

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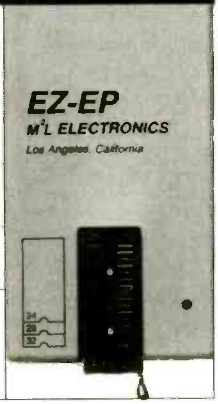

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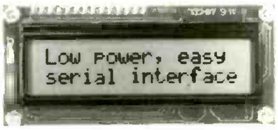

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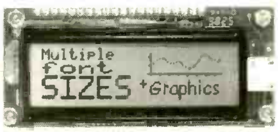

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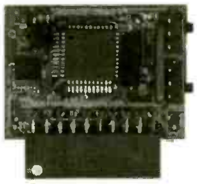

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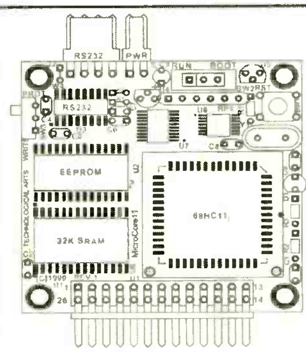

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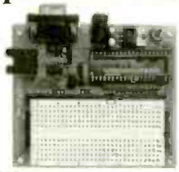

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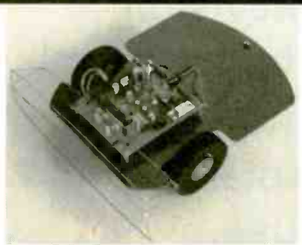

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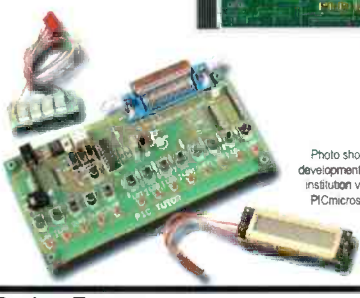

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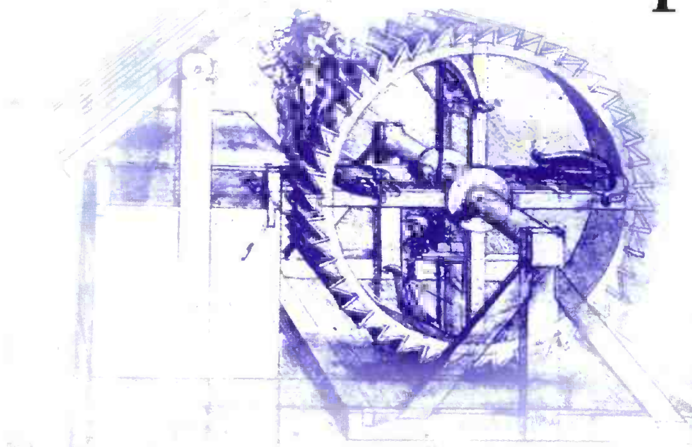

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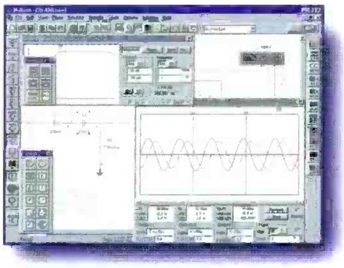

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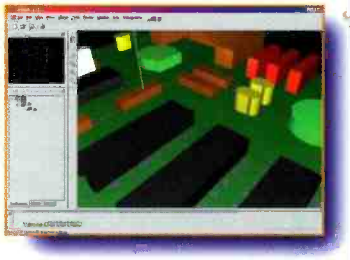

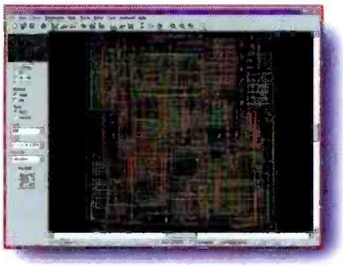

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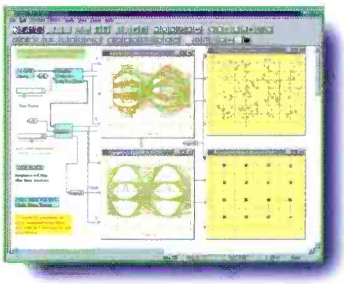

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